The Annual Convention will be held at Burlington, Vermont, September 18, 19, 20 and 21.

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OF THE

New England Water Works Association.

1923.

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THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 800 men. Its membership is divided into six classes, viz:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Life Member shall be a member whose service to the Association entitles him to special recognition by the Association.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

Initiation Fees		*Annual Dues*	
Members	$ 3.00	Members	$ 6.00
Juniors	1.00	Juniors	3.00
Associates	10.00	Associates	20.00
Corporate Members	10.00	Corporate Members	10.00

This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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New England Water Works Association

ORGANIZED 1882.

Vol. XXXVII. June, 1923. No. 2.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

REFORESTATION OF WATER-SHEDS.

BY PHILIP W. AYRES.*

[*Read February 13, 1923.*]

Mr. President and Gentlemen of the New England Water Works Association, — I want to acknowledge my thanks to a considerable number of persons connected with your Association, and to read extracts from what they have said:

The Portland, Me., Water District has been planting 20 000 trees a year for a number of years, at a cost of $20.79 per thousand trees planted. This is a little higher than average cost, perhaps, due to difficulty in preparing the land for planting. The information comes from Mr. James W. Graham.

Word comes from Mr. J. H. Reed of Manchester, N. H., that the Water Works are planting from 50 000 to 75 000 trees every year, and that their oldest plantations, which are about fifteen years old, are looking very splendid, and promise a good revenue in years to come. He sent a picture that will show in the lantern a little later. $1 265 00 worth of timber were sold from the forest of the Manchester Water Works in 1921.

Mr. James L. Rice of Claremont, N. H., reports that they have set 40 000 trees and that they are placing them six feet apart as a rule, but when they find a lot of undergrowth they just fill in the pines and use the undergrowth as nurse trees, which is a good thing under certain conditions.

Very interesting material comes from Newton, Mass., also from the Massachusetts Metropolitan Water Board, and from the New Haven Water Company, which the pictures will show.

From Franklin, N. H., Mr. J. P. Proctor, Treasurer, writes that they have already planted 50 acres and the experiment seems to be very good. He thinks it will be profitable in the long run, besides affording early protection to the water-shed.

From Springfield, Vt., the Manager, Mr. R. W. Wilcomb, writes that they have an excellent showing of trees ten years old. He wishes those interested would come up and look at them.

* Forester of the Society for Protection of New Hampshire Forests.

Much valuable material has been received from the Pennichuck Water Company of Nashua, N. H., through Mr. Arthur B. Graves, who has sent some pictures from which slides have been made.

Mr. Charles E. Warren, Trustee of Waterville, Me., Water District, writes that from six to fifteen thousand trees have been planted annually since 1905, about six feet apart. The result is encouraging, but they are

A Pine Plantation Twenty Years Old, Keene, New Hampshire.
The first thinning has a value sufficient to pay cost of removal.
Planted six feet apart.

finding difficulty from the White Pine Weavel that attacks the top shoot.

Mr. Sidney Lee Ruggles, Superintendent of the Barre, Vt., Water Department reports very interesting plantations of Norway spruce at a cost of $16.04 per thousand.

Let me ask your especial attention to the photographs from the Water Commissioners of Middletown, Conn., who have been planting for twenty years, since 1903, and have about two hundred acres to their credit. Their hardwood plantations, particularly oak, are very successful. They sold $459 worth of wood in the year covered by their latest printed report and have about two hundred planted acres. This information comes from Mr. Eben Jackson, Middletown, and from Mr. W. O. Filley, Forester of the State Experiment Station.

Some very interesting experiments in the re-distribution of native pine seedlings have been carried out on the water-shed of Hanover, N. H. These have been made under the direction of Professor Robert Fletcher,

a member of the Board and long Director of the Thayer School of Engineering at Dartmouth College.

From Concord, N. H., Mr. Percy R. Sanders reports having purchased in April 1908, twenty-five pounds of pine seed, which was set out in beds and later planted over the water-shed. The lantern pictures will show you the splendid results. Some of you are finding great difficulty in procuring small trees for planting. Let me commend to you the Concord way of starting a small nursery for your own use. It is practical and inexpensive.

I think that you will find interesting the following table of plantations in New England, by states. It shows much commendable work.

TABLE OF PLANTATIONS ON WATER-SHEDS IN NEW ENGLAND.

	Acres Owned.	Acres Planted.	Acres Available for Planting.
Maine.			
Portland Water District	540	11	500
Kennebec Water District	305	42	75
Total reported	845	53	575
New Hampshire.			
Manchester Water Works	2 300	513	none
Pennichuck (Nashua Water Works)	900	700	150
Concord Water Works	400	150	75
Claremont Water Works	90	40	10
Jaffrey Water Works	150	135	15
Hanover Water Works	1 281	15	700
Hollis Town Forest	200	15	....
Warner Town Forest	800	5	....
Walpole Water Works	....	25	....
Franklin Light & Power Co.	....	5	....
Total reported	6 121	1 603	950
Vermont.			
City of Barre Water Dep't	334	10	40
Bellows Falls Dep't	400	25	50
Chester Water Works	....	7	....
Hardwick Water Works	1 000	100	500
Montpelier Water Works	....	88	....
Northfield Water Dep't	200	150	50
City of Rutland Dep't	289	220	none
Rutland Ry. Light & Power Co.	3 000	30	1 070
South Royalton Citizen's Water Company	40	10	5
Springfield Village Water Works	50	12	25
St. Johnsbury Water Works	....	213	....
Woodstock Aqueduct Co.	196	7	100
Lake Shaftsbury Association	....	2	....
Standing Pond Trout Club	....	4	....
Total reported	5 509	878	1 840

Massachusetts.	Acres Owned.	Acres Planted.	Acres Available for Planting.
Amherst	....	35	....
Athol Water Dep't	350	20	75
Attleboro	....	15	....
Brockton Water Dep't	100	40	38
Cambridge Water Dep't	778	75	500
Fall River (Watuppa Reservation)	4 000	100	100
Fitchburg (City Ownership)	1 550	200	500
Foxboro Water Supply District	33	8	5
Haverhill Water Works	863	10	75
Holyoke Water Dep't	3 200	200	1 000
Hudson Public Works	275	180	80
Leominster Water Works	90	60	30
Lowell Water Dep't	198	40	90
Marlboro Water Dep't	146	10	20
Needham Water Dep't	....	5	....
New Bedford Water Works	2 000	20	100
Newburyport Water Commission	70	20	....
Newton Water Dep't	600	180	300
Northampton Water Dep't	1 300	100	1 000
North Brookfield	....	5	....
Pittsfield Water Dep't	3 225	600	1 200
Southbridge Water Supply Co	1 482	15	900
Taunton Water Works	155	30	20
Uxbridge Water Dep't	44	10	6
Waltham Water Dep't	67	42	25
Westfield Water Dep't	3 240	100	500
Winchendon Water Dep't	300	250	none
Winchester Water Works	405	200	200
Worcester Water Dep't	3 000	500	100
Metropolitan District (Boston and vicinity)	10 330	2 200	900
Total reported	37 801	5 270	7 764
Connecticut.			
(*a*) *Companies.*			
New Haven Water Co	12 000	1 800	none
Bridgeport Hydraulic Co	13 000	450	600
Ansonia Water Co	2 200	200	25
Naugatuck Water Co	1 206	400	600
Norfolk Water Co	1 100	15	300
Greenwich Water Co	....	200	....
Collinsville Water Co	13	11	2
Woodbury Water Co	150	18	50
South Manchester Water Co	....	20	....
Torrington Water Co	4 401	75	1 500
Rockville Water Co	250	100	75
Thompsonville Water Co	64	5	30
Stamford Water Co	....	50	....
Birmingham Water Co	....	2	....
Jewett City Water Co	....	10	....
Southington Water Co	....	25	....

(*b*) *Municipalities.*	Acres Owned.	Acres Planted.	Acres Available for Planting.
Hartford Water Com'rs	7 200	500	200
Middletown Water Works	1 036	175	none
New Britain Water Com'rs	3 080	180	....
Wallingford Water Dept	844	50	150
Bristol Water Dep't	1 200	40	600
Groton Water Dep't	....	30	....
Danbury Water Dep't	....	10	....
Water Water Dep't	....	50	....
Total reported	47 744	4 416	4 132
SUMMARY.			
Maine	845	53	575
New Hampshire	6 121	1 603	950
Vermont	5 509	878	1 840
Massachusetts	37 801	5 270	7 764
Connecticut	47 744	4 416	4 132
Grand Total	98 020	12 220	15 261

PINE TREES FIVE YEARS AFTER PLANTING.
Concord, New Hampshire Water Works.

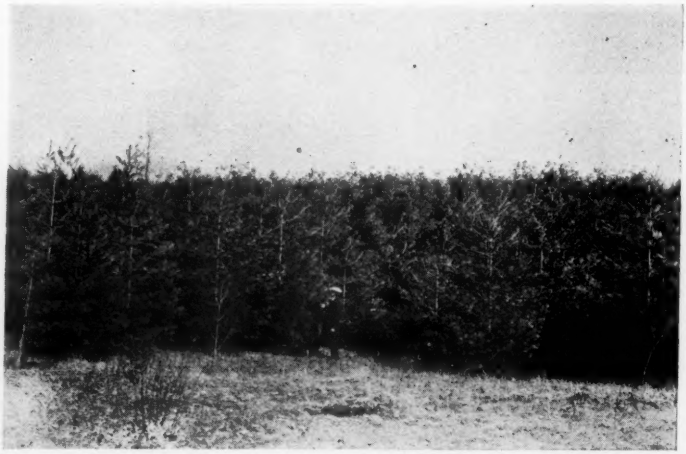
Rhode Island does not seem to have done much planting. The State Forester reports that there is a plantation at Woonsocket, and a very considerable plantation is proposed for the new water-works scheme for the city of Providence. I shall be glad to have further information.

Summarizing, the six New England States have planted approximately 12 200 acres, which have already considerable potential value.

Counting our chickens before they are hatched, when this timber comes to maturity it should be worth $200 an acre easily, which will be $2 440 000, enough to meet in part a possible war emergency. This is an admirable beginning, but what is 12 000 acres against the total amount of waste land we have in New England on our several water-sheds — much of which is not yet purchased.

The Timber Supply.

Let me speak a few minutes on the general bearing of these facts. I shall show you later a picture of the timber condition in this country



Trees on the Middletown, Connecticut, Reservoir Fifteen Years after Planting.

before any lumber was cut at all, and another showing what the Government has done in establishing national forest reserves, in different parts of the country. We ought to realize that in the United States we are approaching, slowly but very surely, a timber shortage. There is no doubt about this. The lumbermen and the leading foresters of the country at large agree that the timber which will give you houses, furniture and tools in the near future is not yet planted, and that our present supplies are approaching exhaustion.

William B. Greely, Chief Forester of the United States, has pointed out that four-fifths of all our remaining timber stands west of the Rocky Mountains, that four-fifths of all the people in the United States live east of the Rocky Mountains, and that there is a long haul between; and he points out that the long haul in coal does not always work out to our advantage and that long hauls in lumber are not likely to work out any better.

Now, we are, according to Mr. Greely, using up our timber in the country at large four and one-half times as fast as it grows. There must, therefore, be an end. You know we had the lumber market formerly in Portland and Boston. It then jumped to Buffalo, at the time when Pennsylvania hemlock came into general use. Then it jumped to Chicago, where it stayed from 1850 to 1880, while the Lake States supplied the growing country with thousands of houses to take care of the immigrants. When the Lake States were finished, it shifted to Memphis and then to Kansas City, where it stayed until nearly now. This was when the southern timbers came into use. They are nearly cut now. You who have finished off houses with southern pine at relatively cheap prices, will see comparatively little more of it. Southern pine at advanced prices is with us only for a little while. The Pacific Coast is now the timber market.

I saw on the streets of Boston yesterday a car load of paper pulp that was imported from Sweden, with notices upon each roll in German and in French, "Don't use any hooks upon this paper." We are already introducing foreign-made paper into this country, and that means that our factories are not manufacturing and that our own people are not employed. Now, you may put a high tariff on it, but if you do, where are you going to get your paper? The lumber that is coming from Oregon through the Panama Canal costs $15 to $18 per thousand board feet delivered in New York and Boston, and the building in which my office is located, within a block or two of here, has recently been made over, and some of the lumber that was used in it came from Oregon.

Now, New England is actually producing only 13 per cent. of the lumber that is used in it per year; and New Hampshire, which is my state, produces only 47 per cent. of the lumber that is used in New Hampshire per year. Vermont has the same percentage. We have in New England six million acres of idle, waste forest land that is producing not even inferior cord wood. We have in New Hampshire 1 900 000 acres of idle forest land that once produced magnificent forests, and ought to do so again.

Now, I mention all these things to you because they have a very direct bearing on the problem of you gentlemen who have planted the 12 000 acres, and who have made the first great, splendid beginning in New England that must be followed by many people in many ways. I think you have set an example. But I am also pointing out that 12 000 acres as against 6 000 000 acres of waste land is not sufficient to more than meet a single emergency.

Mr. Henry S. Graves, formerly Chief Forester of the United States, did a splendid piece of work in France in making ready for supplying the French and the English and the American armies with timber from the French woods, which the French people had been preserving carefully for nearly a century against the great emergency; and when he came back he said that if our war had come fifteen years later than it did, we in America

could not have built our own cantonments without importing lumber to make them, either from a great distance, the Pacific Coast, or from a foreign country — namely, Canada — at great inconvenience and delay.

Now, when you get responsible Foresters to say that, and when you get them backed by the President of the United States, Mr. Harding, who has said that it is a case of returning again to a position of self-defence in America, then you may be sure that the question is worthy of your attention, and that your plantations are likely to prove important to the nation as well as profitable to your selves.

You will be interested also in this, — the lumber that comes through the Panama Canal and pays from $15 to $18 freight rate, means that much of a differential in favor of your growing timber here at home at a profit. I do not believe timber will ever be grown in New England on a great scale except at a profit, and the conditions have not been right for a profit hitherto. The competition of original timber, which is still being mined in the far west, is such that it has not been profitable to grow timber in New England, and our tax system in most of our states has been such that it has been impossible for anybody to grow timber at a profit, except on publicly-owned land. We must change these conditions.

The Bearing of Forest Taxation.

I should like to add a word about forest taxation. For the water companies, it makes a great difference whether you are growing timber on private land or public land, because the private land pays taxes. In most of our New England States, except Massachusetts, no system has yet been worked out by which the tax on private forests will enable you to grow them at a profit.*

I think I can make this clear to you. Suppose you have a few acres of timber, and your annual tax amounts to $20, and you are to cut your timber thirty years hence. Whatever you pay in taxes if placed in the savings bank would draw interest for a term of years. All of these several sums paid in taxes at compound interest for thirty years, or twenty-nine years, or twenty-eight years, etc., must be deducted from the final sale value. Let me repeat. The first year you would compound your $20 for twenty-nine years; the next year the same for twenty-eight years; and so on till the last payment with interest for one year. Now, money in the savings bank will double in fourteen years so that your $20 becomes in fourteen years $40, and in twenty-eight years it becomes again $80. Therefore, you have $80, $79, and so on, which you have really paid in taxes, against the value of your few acres at the end of the thirty years. Now, unless you can regulate your system of taxes — I am speaking now to those who are planting on private land — you will find that they will

*Since the above was written, New Hampshire has enacted a forest taxation law by which growing timber on tracts of fifty acres or less, maybe exempted until the time of harvest.

PLANTATION OF THE CONCORD, NEW HAMPSHIRE, ELECTRIC COMPANY IN 1915.

PLANTATION OF THE CONCORD, NEW HAMPSHIRE, ELECTRIC COMPANY IN 1920.

The same location as the previous picture, five years later.

eat up all of your final profits completely, because from the period of planting until the harvest you have to compound those taxes and take them out of the final product.

The Idle Forest Land.

Now, we have in the eastern part of the United States 81 000 000 acres of idle forest land, and we are importing lumber from Canada, from Sweden and from the Pacific Coast to supply the greater part of the eastern part of the United States, excepting, of course, the South, which, as I said, will end up within ten years. It is estimated that 3 000 sawmills will go out of business in the South within five or six years. These are statements from official sources.

This is not a situation which Americans can first comprehend and then do nothing about. We have confidence, all of us, in one another and in the general American character and common sense, to know that to make these facts generally known is all that is necessary in our free land to get them corrected.

The Remedy.

And where does the remedy lie? Partly in Federal purchase, such as the White Mountains forest and in the southern Appalachians; partly in great state forests. New York has acquired 2 000 000 acres; Pennsylvania, 1 300 000 acres. Massachusetts has appropriated $3 000 000 by which the Conservation Commissioner shall acquire and plant up 100 000 acres of idle land in Massachusetts within fifteen years. That is merely a beginning. There are nearly 1 000 000 acres of idle forest land in Massachusetts, but you have made a fine beginning in getting the thing started by state action. But by far the most important part of the remedy lies in private planting, with such state and federal aid in taxation and otherwise as shall make private planting profitable.

Municipal Forests.

There is a great future for municipal forests in this country. Our problems approach the European problems more and more every year, owing to the increase in population and the scarcity of timber. With us in New England wood has doubled in price in the last ten years. All of you remember that ten years ago spruce and pine were exactly half what they are now.

There are in New Hampshire two municipal forests of especial interest because they are managed by Water Works Departments, and were acquired originally to protect the water-shed. One of these is the Keene forest of 1 800 acres of woodland from which $14 000 worth of lumber has been sold. My belief is that none of this was reinvested in the forest itself, that the limit in cutting which was six inches, amounts

THE MIDDLETOWN, CONNECTICUT, RESERVOIR IN 1915.
Plantation on the farther shore.

THE MIDDLETOWN, CONNECTICUT, RESERVOIR IN 1920.
The same location as the previous picture, five years later.

to very little and that future revenues to the city of Keene from this large timber tract are not as promising as they should be.

In contrast to this, 1 275 acres owned jointly by Dartmouth College and the town of Hanover are managed on a much wiser plan. The mature trees only are removed and the promise of future returns is excellent.

The movement for town forests in Massachusetts is very active, not only to protect water-sheds, but also to provide a future timber supply. Under the active leadership of the Massachusetts Forestry Association twenty-two towns and cities in Massachusetts have established town forests, while more than eighty others have official committees established to locate such areas and define the terms of acquirement. The town of Russell has acquired recently 1 700 acres for water-shed protection, and proposes to plant several hundred acres, the rest being timber land that is well stocked.

Summary.

Summing up, the situation is this: We have all of us to get into the game; everybody at his own house. We shall build well if everybody does that which is next him, and the municipal forest is the one which just now is nearest to us. Later we may plant profitably as individuals, but not now. I have been mighty glad to speak to you today because you are engaged practically in planting municipal forests; these lists I have read to you, are, practically all of them, municipal forests. Now this is a magnificent beginning, and I congratulate you. The only thing is, do not be discouraged in well doing, and continue, especially those of you who are planting on lands which are not taxed. In the long run much will be accomplished.

Now, I can say what I have said somewhat better by pictures, and as a number of those whose names I read, and some whose names I did not read, have provided lantern slides for you this afternoon, I am happy to be able to show them.

(Mr. Ayres then showed a large number of stereoptican views, during the showing of which the following general remarks were made):

Handling White Pine Seedlings.

White pine requires shade while the trees are small, and it will be to your advantage to get your own nurseries started so that you will not have to pay from $8 to $15 a thousand for your stock. The Portland Water Board wrote me that they were unable to get this year more than 1 000 little trees. That is, the State Nurseries and the private nurseries are sold out already, and if you have not gotten your orders in you will have to scurry around to get trees this year. The small nursery is practical if you are going to plant anywhere from ten acres up. By planting your seeds and covering them very lightly, perhaps putting a little straw over them, in the course of a few weeks they begin to germinate. When the

young white pine trees are in the beds, after the shade frames have been taken off, in their third year, they are taken and put in regular garden rows and taken care of just like garden plants. When you plant them in the field you need, as a rule, only small breaks into the soil. Two men can plant a thousand trees in a day,—if the land is reasonably open. Pails are used in the handling, because the roots of the little pine tree have to be kept moist from the time they leave the ground until they are in the ground again. If the roots of the pine tree get dry, the resin in them will

UNDER PLANTATION OF PINE, NEW HAVEN WATER COMPANY.

coagulate and choke the circulation so that the tree will always die. Therefore, be sure that the trees are kept in a moist condition; heel them in the ground and pour some water over them; keep the roots wet until put in the ground again.

DISTANCE APART.

If you plant your trees six feet apart, in time you will need to do some thinning, but at that distance you can make the thinnings when the trees are big enough to pay for their cutting.

DAMAGE FROM ANTS.

Now and then all of you will find some disturbances from big ant hills. We did not know what was the trouble until lately; we thought the ants carried some fungus in the ground which spread to the roots of the trees. But it has been discovered that this is not the case. The ants want the sunshine, and they deliberately girdle the pine trees around.

If you will look closely at the butts of the dead trees you will find that the ants in hundreds have nibbled clear around them, until they have positively killed the tree. How the ants know that girdling will kill I do not know, but they do it in order to let light in on their nests. I once visited the Middletown plantation down in Connecticut, and found considerable damage from the large ant hills.

The White Pine Blister Rust.

Let me tell you something about the White Pine Blister Rust. You are doomed if you do not keep the Pine Blister Rust out of your pine plantations; but I am glad to tell you it is a very simple thing to do. This is a disease which gets into the little needle at the end of the twig, and then runs down into the minor stem, and then runs down into the main stem and finally girdles the tree completely. It is very much like the chestnut blight, which has wiped off $300 000 000 worth of timber from New York, Pennsylvania and the New England States already. And the pine growth, which is worth more money by many million dollars than the chestnut ever was, is very near its end through this new disease, unless we keep the disease out. But fortunately we have now a method of keeping it out, namely, by carefully eradicating all currant and gooseberry bushes, both wild and domestic, from within at least one thousand feet of the pines. The disease develops on the currant and gooseberry bushes.

This is done at an expense of from twelve cents an acre on high land to $1.79 an acre on swamp land. I urge you to make sure you get it done. The cost is usually under thirty cents per acre. The State Forester will send crews of trained men to you, who are efficient, if you will merely pay the bill, and in New Hampshire literally hundreds of private owners have taken advantage of this offer. The same is true of Massachusetts, Connecticut and elsewhere. So be sure that you are free from this pest, and be thankful that you can be free from it.

The National Forest in the White Mountains.

You will be interested in the National Forest Reserves, that the Federal Government is establishing by purchase in the Eastern Appalachian Mountains. Congress has appropriated a total of $12 000 000, and something over $2 000 000 has been expended in the White Mountains. Forest land has been acquired (440 000 acres or 700 sq. mi.) at an average price of $6.23 an acre. It is estimated that that timber would now sell for a million dollars more than the total cost to the Government. It therefore has been an excellent investment. The White Mountain forest is now entirely self-supporting, and soon will return goodly revenues to the Government.

In this matter we owe a lot to a number of Massachusetts men. I was going to speak of John Weeks as a Massachusetts man, but I believe

we can fairly call him a New Hampshire man. John Weeks's grandfather was a member of Congress from the Northern District of New Hampshire. It is said that he had eight sons, all six feet tall, and that he used to line his boys up along the wall and say, "Look at them; look at them; I have fifty feet of boys." Well, we owe much to John W. Weeks.

We owe much to Dr. Edward Everett Hale, who surveyed the White Mountains when twenty years old, and sixty years later when Chaplain of the Senate worked to get the bill through that the White Mountains might be taken over by the Government.

Just one point about New Hampshire. There are comparatively few states that have made a survey of their forest lands and know what the condition is. We have made this survey. We have 29 per cent. of our lands in splendid, promising growths, but we are very sorry that we have a third of our state, very nearly 33 per cent., which is in idle, waste condition. The worst of it is that in New Hampshire, as in Massachusetts, and all the New England States, we are increasing the idle and waste area. We are cutting off in each of our states about 50 000 to 75 000 acres a year, about half of which comes back to good forest. To solve our forest problem we must plant as you are doing, but also we must change our methods of logging, and that right speedily, so that a desirable species returns upon the land, and so that our great unnatural areas of waste forest land are not made still greater.

Discussion.

President Sanders. There is one thing up in New Hampshire that we are mighty proud of, and that is our mountains and our lakes and forests; in fact, those are really the principal assets of the State.

About twenty years ago a number of the public-spirited men of New Hampshire got together, and they made up their minds that unless they did something pretty quick their lumber interests would clean those hills and mountains all off. In lumbering they did not take any particular care to dispose of the slash, to do any reforesting when they cut off, to look out for fires, or anything of that description. So these people got together and organized a little society — the Society for the Protection of New Hampshire Forests, — and everything that has been done in the forestry line in New Hampshire can be traced back to this Society. They have been back of every move, — reforesting, planting small trees, looking after fires and fire wardens, and planting shade trees; and the man who has stood behind all of those movements, the man who has put his shoulder to the wheel and pushed things through, is Mr. Ayres.

Now, Mr. Ayres I know will be very glad to answer any questions that anybody would like to ask him. Before that, I should like to ask if Mr. Orr is here; for if he is, I think we should like to hear a few words from him.

MR. ALEXANDER ORR.* *Mr. President and Gentlemen:* Under my direction one of the first municipal forests in the State of New York was started and is maintained. Our Board of Water Commissioners in the early nineties became convinced of the desirability of obtaining by purchase or otherwise the various acreages of land contained in our water-sheds. This policy was pursued for a few years until we finally found we had a large accumulation of land on our hands and it did seem a shame not to put it to some actual use.

Previous to 1908 we did a little planting by taking up seedlings around the old pine trees, with not very good success. In 1908, with the help of Mr. Whipple and the State Fish and Game Commissioner of New York State, we planted our first planting of seedling trees. There were 10 000 white and 10 000 Scotch pines. They were planted five by five. Each year subsequently we have planted from 30 000 to 120 000 trees.

In our accumulation of water-shed land, on one water-shed we acquired about two thousand acres. That was made up of an area of sixty acres of water, about seven hundred acres of grass land, gardens, pastures and fields of the farmers we had taken, and the balance of it was practically all hardwood. We then planted all those open areas with white and Scotch and red pine, and spruce. After a year or two we changed our method by making the spacing six by six.

The state of New York about that time commenced to encourage the reforesting of waste land in New York State, and urging it upon the people, who began replanting so much that the state supply of transplants became very scarce, and we inaugurated our own nursery. We continued that nursery over a period of ten years. Along about 1910 the scarcity of transplants was so great that we, with several others, imported from Germany through the State Department a number of pine trees. That importation finally, I think, probably did more to introduce the blister rust in the United Sates than anything that has ever been done. Those trees were in about six years, and we finally cut them all out and burned them.

As Mr. Ayres said, it is easy to eradicate the blister rust if you chase around and eradicate the wild gooseberry and wild currant bushes, but it is a pretty hard thing where you are surrounded by farmers who raise gooseberries and currants.

We also found another trouble with our white pine. We got our trees started along nicely, and along came the weevil and cut the leader off, and the result was that we have quit planting white pines altogether. We plant now only red and Scotch pines, and spruce trees. We plant on all of our open areas. We have trees that were planted in 1908 that are now twenty-eight feet in height.

One of our worst fears is the fear of fire. We had a fire two years ago in which we lost about thirty acres of Scotch pine. A match was dropped out of a wagon on a road passing through that section.

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* Superintendent Water Works, Gloversville, N. Y.

There was originally an electric railroad and three country highways running through the two thousand acre plot that I spoke of, and since we have acquired it we have built a private highway of our own through practically the center of it. We have succeeded in closing up the public highways entirely to the public. The electric railroad has been abandoned. Now, there is one thing for fire protection that we do. We keep the right of way of this railroad and a fifty-foot strip along the highways and our private highway mowed every year. We keep it stripped. There is no dry grass in it.

Another experience which we had with the fire which I spoke of was in a patch of Scotch pines which had been planted about nine years. Under those pines was from two to four inches of nice dry needles, good food for fire. When the fire got into those needles it did not take long to catch the lower dry dead limbs, with the result that we have growing there today probably not over one hundred trees, the rest being absolutely killed.

We are now starting in and going through the trees that are up in size, trimming the dead limbs off, and taking them out and burning them. I have been criticised by some foresters for taking out a few live limbs, but I think I would rather have a few knots there thirty-five years from now than not to have any trees.

Now, we found last fall in going through some of those plantations two or three places where evidently some camper had started a little fire on the pine needles and the fire had burned out, doing no damage to the trees.

For about two years we have been cutting off hardwood timber, and we use that as spare-time work for our workmen. This place is only three and one-half miles from the city. We can go there with a motor truck up to the time snow starts and on such days as the weather is not too severe. The cord wood is sold by the Water Department and bought pretty much by the employees. It has been a source of a great deal of satisfaction during the past few years in the coal crises.

The following spring we go over that same area and replant with evergreen trees. We figure in the course of years that particular tract of land will have the hardwood all cut off, and that following up the cutting with evergreen planting, by the time we get that done we are ready to start in cutting off marketable pine and spruce timber. We started in 1908.

I will say for New York State that there is a provision of the tax law by which reforested lands are exempt from taxation for a period of years. My recollection is that it is thirty years. The provision is that the lands which contain a certain number of acres shall not be located within a certain number of miles of a city of the first, second or third class. Unfortunately we can not get into that because we are too close. But that gave great encouragement to reforesting work in New York State. The intent of the law is that there shall not be any excess valuations put on the property until the end of the thirty years, and then assessed at a valua-

tion in accordance with the value of the standing timber on it. A few people have taken advantage of that provision, but the amount of red tape necessary, has nullified the benefits of the exemption.

The state of New York this year has made a tremendous effort to influence people owning waste land in New York State to take up this reforestation work. They are offering special inducements to land owned by divisions of the state like towns, counties and municipalities, like water-shed lands. This year I understand they will furnish them trees for nothing where a few years back they were furnishing for fifty cents a hundred — the highest price they charged to private owners was some four dollars and fifty cents a thousand for four and one-half year old white pines. I understand they have over 4 000 000 trees to hand out this year, and three months ago that allotment was entirely taken.

MR. RICHARD A. HALE.* May I add one word? We are under great obligations to Mr. Ayres for coming here and talking to us today.

There are very few who realize how much work he has put in in connection with the White Mountain Reservation and the results which have been accomplished. I think those of us who have been in touch with him in connection with the water-power proposition of the Merrimack River realize what he has done in that respect.

In connection with that perhaps I might mention that there was a report by the United States Engineers published a few years ago in regard to reforestation along the Merrimack River, and the results in regard to stream flow. That was six or eight years ago. They made a study of a period of sixty-years' flow of the river at Lawrence with reference to the effect of cutting the forests over the drainage area. The results did not indicate any diminution or irregularity of flow which could be attributed to this cause and many other conditions had to be considered of greater bearing on the subject. A small undergrowth had sprung up where the forests had been cut which gave a partial protection to the ground and did not leave it entirelybarren. It is, however, very desirable to have a good forest growth over the water-shed to protect the moist humus of the soil.

* Engineer, Essex County, Lawrence, Mass.

THE DIESEL OIL ENGINE FOR WATER WORKS SERVICE.

BY DR. CHARLES E. LUCKE.*

[*March 13, 1923.*]

The subject before the meeting is not an ordinary one. We have come before you to announce what we believe represents a new era in water-works practice, one that offers possibilities fully as great as were brought in by the centrifugal pump and the steam turbine; this is the oil-engine-driven, water-works pump.

Water-works practice in the past has been characterized, in comparison with other branches of steam engineering, by two great distinctive features. One of these is very high thermal efficiency, higher than is obtained in any other branch of steam practice with equal size of units. The other feature of great significance is the recognition by water-works people of the value of investment, the importance at times of investing more money in first cost of installation to save fuel, and its justification by the high average load factor that characterizes a water-works load in comparison with the lower average load factor typical of central station loads.

Water-works engineering, or, rather, the steam engineering phase of water-works practice, has been in those two respects probably in advance of all other branches of engineering practice. In the course of time we have seen various new forms of steam equipment developed, reach a commercial stage, come into use and finally appraised in comparison with what went before. The steam turbine has come with its centrifugal pump and that added a totally new class of different types to what we had before, represented by a series of different kinds of piston-reciprocating steam engines and displacement pumps.

Looking back over this period of development of the steam turbine in the general-power field, one must note that parallel to it there has been another development, the consummation of which we are just announcing. This other development has been the internal-combustion engine, but particularly the Diesel oil engine, which is characterized by the highest thermal efficiency ever accomplished in any prime-mover burning fuel. That high efficiency was proved a quarter of a century ago. It has taken all this time to bring the engine to a point where we feel it is properly reliable, available in suitable forms and safe to use for water-works practice in competition with all kinds of steam installations, each case to be judged on its merits and the merits to be purely economic and in no sense prejudicial.

* Professor Mechanical Engineering, Columbia University. Consulting Engineer, Worthington Pump and Machinery Corporation.

In this situation Worthington is in a unique position, unique in this sense, that Worthington is prepared to build and has built, as you all know, every type of steam equipment and of every size, and is now embarking on the enterprise of offering for every type and size for which there is any justification whatever, a corresponding Diesel oil-engine, water-works equipment. One type of Diesel engine must be judged against another, one type of pump equipment must be judged against another, any steam equipment must be judged against any Diesel oil-engine equipment. Selection must be made on the same basis for all, the best for the local conditions, worked out on an engineering analysis of the facts, each engineer making his decision on facts, without opinion or prejudice making any difference whatever.

This, gentlemen, is the first announcement of such a position by any organization in the world, so far as we know, and it is particularly interesting to all concerned because Worthington makes the announcement with an unprecedented variety of experience and present variety of equipment as a basis for its judgment.

This judgment is supported by certain facts and principles, certain developments that have become stabilized, and it is worth while to review some of the high spots of the development to show what seems to be the fundamental basis for the confidence that we have and which we think will result in your confidence in the future.

The Diesel oil engine has been growing most rapidly on the commercial side in the motor-ship branch of its application and use. There are now on the seas some hundreds of motor ships, on long-voyage routes such as from Europe to China ports, and these have been operating long enough to have demonstrated the reliability and efficiency of the Diesel motor ship in competition with steam. This situation is particularly important when we come to consider water works because there is no load, no commercial or practical load condition for any prime mover, which so nearly approximates that of the water works, as the load of the engines of ships which go on long voyages where the engine may run without any change whatsoever in its revolutions or load for as much as two months, and then just stop long enough to unload, reload, turn around and repeat.

That progress, however real and substantial, is not in itself sufficient. The engines of these motor ships are large and they have to be brought down into smaller sizes to meet the load or the capacity requirements of the various kinds of water works. It is not good policy to start building water works with Diesel ship engines in just one or two sizes; it is better to wait until the entire field can be covered with what would be most suitable, as to size and type, one for one plant, and another equipment for another plant; to wait, in other words, until a fairly complete line of sizes and types has been made available. An additional development, therefore, was due to take place, the adaptation of the Diesel engine to smaller sizes, and that has now been consummated and become a reality.

Still further improvements are needed, however, for water-works use of Diesel oil engines, development of application or connection of the engine to the pump. Here it is necessary to recognize that the r.p.m. of good oil engines are normally much less or much greater than the r.p.m. of good pumps, centrifugal or displacement, so that gearing becomes necessary in most cases, although not in all. This gearing problem becomes most acute, or, rather, most difficult from the old-fashioned standpoint, in the gearing up of the centrifugal pump so as to get its best speed when the engine runs also at its own best but lower speed.

It is recognized that gear development has just completed a piece of history. Gearing has been a problem primarily, for the steam-turbine engineers and they have succeeded both in stationary practice and in ships in making good gear sets transmitting from a few horsepower to many thousands. Gearing has today reached a state that has never been before even approached in the history of machinery. What is being done now with gearing would have been pronounced, say fifteen years ago, as a hopeless impossibility. We now realize that we did not know at that time anything at all about gearing.

It may be said, therefore, that there are three great developments which together serve as the basis of what we now are approaching, the application of a Diesel oil engine to water-works practice. The three developments are, the motor ship Diesel engine, that is the first, next, the adaptation of the Diesel engine to smaller sizes, as small as one might please to have, and with a certain increase in simplicity at the same time, and thirdly, the development of gear practice.

Coming down to the engine itself, there are certain things that are fundamental, the understanding of which justifies confidence, and the realities and truths of which are responsible for what has already been accomplished. Without going into tiresome detail, it is, however, possible to show the essential simplicity and firm foundations on which the big ideas rest.

The first and the most important function to be performed in a Diesel engine is to get a charge of air into the cylinder. The next important function is to get a charge of oil into the cylinder. Then the important thing is to bring that air and that oil together in such a way as will insure ignition, and in such a way as will insure that the combustion which follows ignition shall take place at just the right rate, neither too fast nor too slow, because too fast makes abusive shocks and too slow loses efficiency. And finally, when combustion is completed, this contact between the fuel and oil must have been so accomplished as to leave no fuel unburned and as little as possible unused air or free oxygen in the exhaust.

Here, in a way, is the complete story of the functioning of a Diesel engine that is not common to other machines. It is these particular things that make a Diesel engine *Diesel* and distinguish it from everything else.

It is desirable to examine a few of these points in more detail. First, consider the air charging. There are two great systems of air charging and each is good, each is suitable, but each has a different most appropriate application or use, which is learned by experience.

According to the first mode of charging the cylinder with air, it is provided with two valves, always poppet valves, an inlet and an exhaust, and these two valves are actuated by cams which are timed properly on the cam shaft which is gear connected to the main crank shaft and runs at half speed. It may be said, therefore, that the first system of charging is a valve system form of charging, consisting of a gear-driven, half-speed cam shaft, with a set of cams for operating an inlet and an exhaust valve for each working cylinder, and this technically and commercially is called "the four-cycle system."

The second system of air charging has proved to be well adapted to smaller sizes where simplicity means most. This is the system of charging by simply cutting two ports in the wall of the cylinder, very much in the location characteristic of exhaust ports of the Unaflow steam engine. The two ports are opposite each other. One is simply a vent for exhaust gases to permit the pressure in the cylinder to drop to the atmosphere when the piston passes that port at the end of its stroke. Immediately afterward the air port on the opposite side is opened by the same movement of the piston to a supply of air made available at that port by a so-called "scavenging pump," at 2, 3 or 4 lb. pressure, depending on the speed. That air then blows in as a more or less gentle blast, blowing the exhaust ahead of it. Then the piston rises, closes first the air port and then the exhaust, and the compression follows. This is the "two-cycle system" of air charging.

The second system, two-cycle charging, while occasionally used for larger engines, is especially well adapted to small ones because it eliminates the gear-driven cam shaft and the two valves per cylinder, but it has to provide for its air supply by some kind of a scavenging pump or air blower. In the smaller engines the scavenging air displacement is accomplished by utilizing the under side of the working piston in any one of several more or less convenient fashions open to the taste of the designer.

So much for two systems of air charging. One engine will naturally compare with another as to details according to the taste of the designer or the judgment of the user, but between those two systems a first choice must be made.

Consider next the preparation of the air for fuel charging. After the air is in the cylinder, introduced by any one of these charging means, the second step to be carried out is one of preparation for the entrance of the fuel. That second step is a high compression, a compression of the air from whatever temperature it has at the moment the piston starts, to a value high enough to ignite any fuel that may be injected or projected into it. And that high compression is all there is to the ignition system of a

Diesel engine. The ignition temperatures of the various grades of fuel oil are subject to study by physicists who are interested in physical properties, and they give us values. It is a simple sort of calculation to determine how much compression of cool fresh air would bring about a final temperature of 1000°, 1100°, or 1200° Fahrenheit, which is about the range required for most fuel oils. The second stage of charging, then, is really not charging but a preparation for the entrance of the fuel and this is nothing more than the simple operation of compression, again very similar to what takes place in a Unaflow steam engine to superheat the steam in the clearance. Everything is now prepared for the entrance of the fuel and this is the second part of the main functioning system of the Diesel oil engine. The fuel is always delivered in the Diesel engine through a pump and the fuel pump is an accurate device that has metering properties or characteristics. The pump is a finely-made piece of mechanism that meters out most accurately a charge of oil suitable for the load and directly under governor or hand control. Every different designer has his own little details of fuel pump, but there is such a pump with that metering function on every Diesel oil engine.

The metered charge of fuel oil is delivered into the cylinder in either one of two characteristic ways, one quite different from the other. In the older standard air-injection system, compressed air is used to finally put the oil into the cylinder. The pump delivers the fuel, not directly into the cylinder but into the casing of a fuel valve located on the cylinder head, and that casing contains an air space and that air space is in communication with an air-pressure bottle, where the pressure is maintained by an injection air compressor at about 1000 lb., or sometimes less, and that air is constantly available and constantly maintained by the engine because the compressor is directly connected or attached to the engine itself.

There is in addition to this air space in the fuel-valve casing, a place to receive the pump delivery of fuel oil. There is in addition to these things in the spray-valve housing, a stem or valve proper which is cam operated by another cam, a fuel cam, and at the right time, which is about top dead center, the fuel cam operates the fuel valve and whatever oil is in the valve housing is blown into the cylinder. The air at 1000 lb. in the fuel-valve casing blows into the cylinder where the pressure is only half as much. The fuel delivered by the pump is deposited on extended metal surfaces, a sort of a labyrinthian surface arrangement in the valve housing, and it is just blown by the air flow over these surfaces. The fuel, therefore, is delivered into the cylinder by the flow velocity of this compressed air blowing past it into the cylinder. Now, the rate at which it enters is of course controlled by the surface of the metal to which the oil sticks and from which the air velocity tears it off.

All of this is the air-injection fuel-spraying system, which is the one used on all large Diesel engines. This system includes the following ele-

ments: A metering pump delivering a governor-controlled charge of fuel to a fuel valve on the cylinder head. Air under pressure and self-maintaining, acting also in the same spray-valve case. A needle valve through the casing, cam controlled. At the right moment the valve is opened and the air blows into the cylinder, carrying oil with it, at a rate depending on the air velocity and the resistance of the labyrinth that holds back the metered oil. By means of the rate control the combustion can be made fast or slow. The time when it starts to enter is a cam-controlled matter. The rate at which it enters depends entirely on the labyrinth, and that is always made adjustable, so for a thick oil it can be set one way and for a thin oil, another way, absolutely under the control of the operator. So the rate of combustion is controlled by flow conditions. The time of starting combustion is controlled by cams. Ignition, well, that just takes care of itself because the compression is so high that the fuel ignites as soon as it enters.

The second system of fuel injection is that known as solid injection, and it has been especially developed for use in the smaller sizes of engine, where simplicity is a matter of much greater importance, even at the sacrifice of some little refinements for efficiency. With the solid injection system the compressor for blowing the fuel into the cylinder is omitted. With no spraying air it becomes necessary to provide some alternative method of controlling the rate of entrance of the fuel into the cylinder, and therefore the rate of combustion, because that must not be too fast or too slow. This is accomplished by a special means peculiar to each different solid injection engine. However, common to practically all of them is this feature: that the pump now delivers fuel oil directly into the cylinder without interposition of any valve on the cylinder head at all, but there is of course a non-return check. Also common to all is the feature of having this pump not only act as a metering pump under governor but also a timing pump. It times the entrance of the fuel by its own connection to the cam shaft and therefore does within the pump what the fuel-valve cam did in the air-injection system.

There is left only one other function to be provided for and that is the control of rate of burning to avoid the shocks of too fast combustion and the losses in efficiency that go with too slow combustion. Every different solid injection engine has a little different scheme of controlling the rate of combustion peculiar to it and these cannot be examined in detail.

It is clear from these facts that the main idea, the basic scheme of operation in Diesel engines, is extremely simple. There is not the slightest element of mystery or uncertainty or unreliability about it. There are means for getting an air charge into the cylinder, for compressing it enough to ignite the fuel to come, for a proper injection of a metered quantity of fuel oil under governor control, with something to control the rate of combustion, and the time when the ignition or the injection shall start. Naturally the details of carrying out these principles will be different on each

different engine, quite the same as is the case with valve gears on steam engines, but each one of hundreds of varieties may be perfectly good if they conform to the standards built up by the experience of practice, and there need be no uncertainty today on these matters.

In addition to these main functions, which are so essentially simple in idea, conception or principles, there are certain other things which have to be carried out in order that the Diesel engine shall be an engine. The first of these, to distinguish them from those just discussed, may be called " preservative functions."

Any internal combustion engine must be provided with means for protecting itself against destruction. There are two classes of destruction to be considered, one common to all internal combustion engines but not found elsewhere, the other common to all machinery regardless of what kind. The first sort of tendency towards destruction, or the first influence which, if left uncontrolled, would cause destruction, is heat. Heat is generated in the cylinder of the Diesel oil engine at rates that range from low values to very high values and it is an interesting fact to note that the highest rate of combustion measured in b. t. u's per hr. per sq. ft. of combustion chamber exceeds the rate which is common to the most heated portion of steam boilers working under forced conditions. This means that the walls of the chamber in which the fuel is burned in a Diesel engine may be heated as intensively, and in some cases more intensively, than the fire-box plates of a locomotive or the tubes of a water-tube boiler in the range of the radiant heat of the glowing fire. Therefore, there is a tendency from this cause to destroy the metal, but that tendency can be controlled by the same sort of study of engines as has been carried out for the protection of steam-boiler tubes and locomotive fire-box plates and, again similar in another art also successfully executed, the water-jacketed bosh of the blast furnace.

The means whereby the metal walls of the combustion chamber of the Diesel engine are prevented from destruction by heat need not be examined in detail here. It is sufficient to say that we recognize the conditions and we recognize the relation of these conditions to the rest of engineering practice where heat in its effect on metal temperatures must be controlled, and that from all sorts of heat experiences in whatever art they may be found, conclusions are drawn for the solution of these problems.

As a basis of dissipating heat and as the fundamental basis of controlling metal temperature, the circulating water jacket is used. The jacket may be limited to the barrel of the cylinder or its liner, we may include the cylinder head, the piston may be included or not, water may be used or oil, and the water may be fresh, clean water or foul water. These are all questions of engineering that belong in the province of the designer and the installation engineer, and it is sufficient to say that they are now well understood and it is possible to meet any conditions that arise.

Along the line of preservation in the other direction common to all machinery, there are two divisions. The first is resistance to destruction by excess stresses. The preserving of machine members from excess stresses is no different problem in a Diesel oil engine than it is in any other kind of an engine or pump or compressor. This is simply a branch of ordinary machine designing. If the metal stresses due to the forces developed in a machine are computed, it is routine practice to apply the rules of machine designing that have been so many years in becoming established, to this case, and insure equal reliability against breakage.

On the matter of wear, which is the second item here, the situation is not entirely the same. Prevention of destruction by wear has, in some cases of recent development, followed new lines and succeeded, where the rules of old practice would have made these particular developments impossible. It is safe to say generally that wear is primarily the result of metal to metal rubbing contact and that prevention of metal to metal contact will prevent wear. It has been proved to be possible to come extremely close to preventing metal to metal contact by the very modern force-feed system of circulating lubricating oils. This circulating system of force feed of lubricating oil to the bearing comes near enough to prevention, by keeping the shaft or pin floating, to eliminate practically all wear in proportion as it is intelligently applied and more or less regardless, though not entirely so, of the quality of the oil. It is also pretty safe to say that without a force-feed-circulating system of lubrication there would be no modern steam turbines and no air-craft engines. The Diesel oil engine, especially in its motor-ship development, which has been the most remarkable, has adopted it and it is very doubtful if the success that has been attained would have been possible without it. Many early experiences, before it was adopted, were full of grief, but those have all disappeared and we are now on safe ground with the question of wear prevention, even with very high bearing pressures, judged by old standard practice with slow-moving machinery where the film had to distribute itself without the aid of a pump, constantly driving a great excess of oil between the rubbing surfaces with no regulation or adjustment whatever.

With this general idea as to the fundamentals of the Diesel oil engine, which can be expanded and illustrated at any length one may please, the present Diesel oil engine will be found in several different styles and types, each with great variety of detail but all having the same big ideas incorporated. There are available two-cycle engines, mostly in the smaller sizes, for simplicity. There are also available four-cycle engines, mostly in the larger sizes where refinements even with some complication are worth while and where the most intelligent attendance, by reason of size, is likely to be provided; so that there is first a choice between two-cycle and four-cycle, mainly on the basis of size, though not exclusively so.

Again, in the matter of style, practice recognizes a second basis of choice between horizontal as compared with vertical. There are vertical

stationary engines and horizontal stationary engines, thereby repeating the history of steam engine practice, and likewise high-speed and low-speed differences. There is not much to choose between them except in the ordinary sense of engineering as to what is best for local conditions. If equally well designed, it is fair to say that one is quite as good as the other, but not necessarily for the same service conditions.

Again, there are the air-injection engines as compared with the solid injection. The air injection is a little more complicated, but so far a little more perfect in handling the fuel oil. The solid-injection engines are quite satisfactory as far as reliability of service is concerned, but so far more or less confined to the smaller sizes, not so much because they can't be made in the larger sizes but because so far they have not been. Solid injection of fuel oil presents some little difficulty, requiring study to find good solution of the problem and all builders have not yet succeeded, but it is hoped that some day the same degree of simplicity now typical of the smaller solid-injection engines may become available in all the sizes. Just at present this is not true so that there are solid-injection engines mainly in the smaller sizes and almost exclusively air-injection engines in the larger ones.

As to the over-all performance of these Diesel oil engines, probably the simplest way of putting the matter in a few words is this: that the thermal efficiency is determined primarily by the pressure at which combustion stops, not when it starts. Other things being equal, the higher the pressure at which combustion is completed, the lower the fuel consumption, and so the higher the thermal efficiency. If combustion is delayed so that it only completes itself at half stroke, with perhaps less than half the highest pressure, then the fuel consumption is bad and the efficiency is low. Therefore, assuming that is so, assuming that engines have the same compression to insure ignition and that through the design the correct timing of combustion is assured, as correct as one could time the cut-off of an old steam gear, then it necessarily would follow that all Diesel engines could have the same thermal efficiency on the indicated horsepower basis, and that is true. That efficiency generally is in excess of 30 per cent. approaching 35 per cent. on the net horsepower basis, a situation that is remarkable in comparison with steam. In addition, the Diesel oil engine performance has a feature of still greater importance, a most amazing thing judged by steam practice, and that is the independence of this very high efficiency with reference to the size of the engine or its horsepower. To get the maximum efficiency with steam, big units are necessary. Central station practice is building 50 000 kilowatt turbines to get the highest efficiency, which corresponds to between 10 and 11 lb. of steam per kilowatt hour. Can that be done in 100 h.p. unit? It cannot. With steam, therefore, the efficiency rises with the horsepower capacity of units and the highest efficiency requires very large units.

With the Diesel engine, this is not so. With the smallest Diesel engine we can get almost exactly as good an efficiency, within 10 per cent. or thereabouts, as with the largest one, and therefore the application of the Diesel engine just necessarily leads into a different rule of practice than is proper for steam, the practice of using a multiplicity of small units in the place of concentrating into a few of large possible size. The combined thermal efficiency of five small Diesel engines of a given capacity is just the same as one large engine of five times the capacity, and that is not true with steam.

Comparing steam and Diesel oil engine efficiencies, one might say that as efficiency rises with size in the case of steam, it tends toward but never reaches the horizontal or constant efficiency line which is characteristic of the Diesel engine, and independent of size. One might also almost say, and it would not be much wrong, that the curve of efficiency of steam engines or turbines regardless of type, plotted vertically, against horsepower per unit plotted horizontally, is almost asymptotic to the horizontal constant efficiency line of the Diesel oil engine, and would meet it at infinity.

On the matter of fuel available, it is important to note that the Diesel oil engine requires a liquid fuel, but that it is capable of burning any liquid fuel regardless of chemical composition or physical properties, except one, and that is, fluidity or viscosity. An oil that will flow through a pump and permit itself to be metered and that will flow through a valve and permit itself to be sprayed, an oil that is sufficiently fluid to permit those things, is a perfectly available fuel. There are places, in different parts of the world, where such a fuel is not obtainable, but where a heavier fuel is obtainable, fuels, for instance, that may, at the temperature of the room, be as solid as vaseline. Those fuels become available by heating, because it is a characteristic property of all of these fuels that by heating they increase their fluidity, but the addition of a heater means another auxiliary part, not to be used except in cases of necessity.

On the other hand, the steam plant with which it is necessary to compare the oil engine, may burn coal or oil. The choice of one or the other may depend entirely or primarily on the cost of the fuel in one or the other forms on a b.t.u. basis. To facilitate such comparison, the chart has been prepared, Fig. 1, Cost of Fuel Per Million B.T.U., Coal and Oil. That is a very useful chart in comparing the coal-burning steam plant with the oil-burning steam plant or the oil-burning Diesel engine, as to the relative values of one fuel compared with another when dollars per ton or cents per gallon are known with calorific values. By this chart and the over-all thermal efficiency, the fuel cost per horsepower hour can be determined.

Next in importance as an item of operating expense is lubricating oil. Many people seem to think that the lubricating oil consumption of the Diesel oil engine is excessively high because they use so much in automobiles. It is not anything of the kind and just two figures, round num-

bers, easily kept in mind, will completely disprove that common comparison. In the small sizes of Diesel engines, the lubricating-oil consumption is better than 2 000 h.p. hrs. per gal. and in the large sizes it is better than 4 000 h.p. hrs. per gal. for all bearings plus the cylinders. Whatever oil is fed to the cylinder of a Diesel engine is gone, lost, not recoverable, but the oil fed to bearings is never lost provided the engine is so designed as to prevent the foul oil from the cylinders coming in contact with the clean oil circulating through its bearings, as is the case with the better ones.

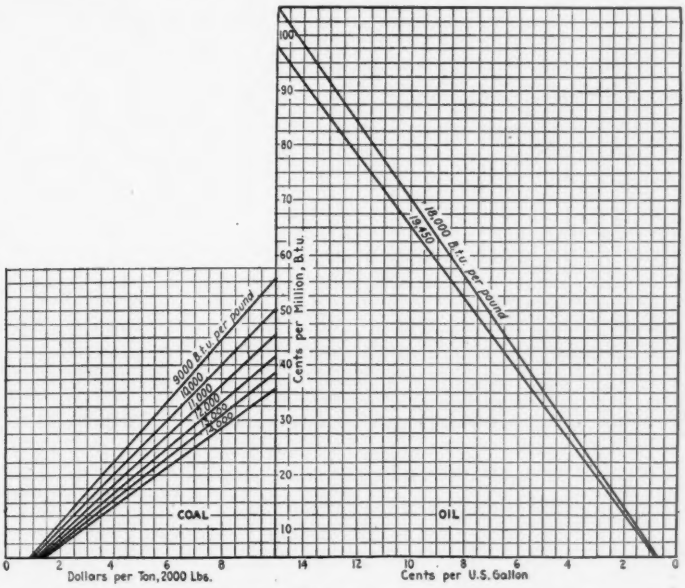

FIG. 1. — FUEL COST PER MILLION B. T. U. COAL AND OIL.

Finally, there are two features to be mentioned in connection with city installation, namely, smoke and noise. On the matter of smoke, attention is called to this universal characteristic of all well-designed, air-injection Diesel engines; that is, they are absolutely smokeless. As a matter of fact, the least little smoke occurring at the exhaust is an indication of derangement and is a warning to fix something, while the absence of the smoke and the clearness of the exhaust is an assurance of good condition. However, in the smaller sizes, and especially with solid injection, and particularly with the two-cycle where the piston is rubbing over the ports, the absolute smokelessness is not quite reached. The combustion may be quite as clean as in a four-cycle engine, but some little lubricating oil rubbed off at the exhaust ports makes a faint haze and a similar haze may result when solid injection replaces air spraying so that in the small

engine the condition of the exhaust is that of a thin transparent or hazy sort of light smoke. Anything more than that is not good and can be corrected, and when everything is just right, complete transparency may result.

Considering noise, two sorts of noise must be noted, the exhaust and the machinery noises. The machinery just naturally makes a sort of

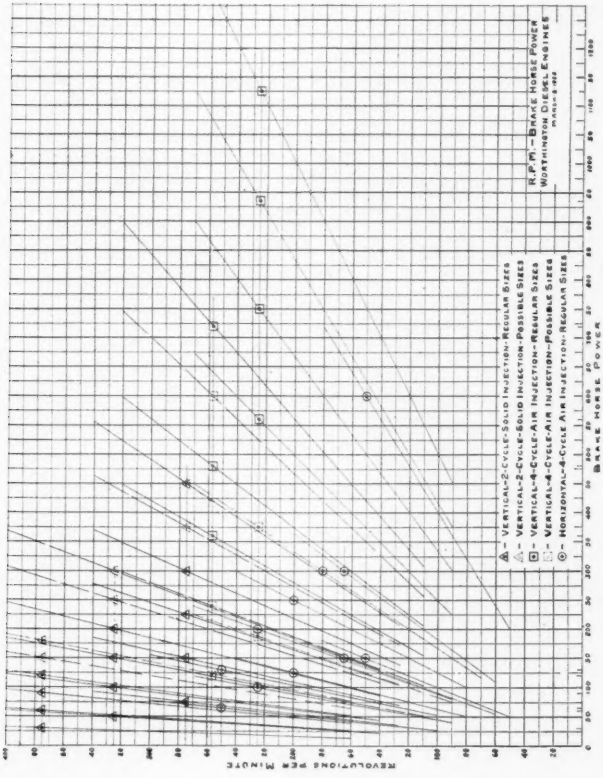

FIG. 2.

rumbling, such as is common to any machine, depending on the size to some extent, also on the foundations and on the echo conditions of the room walls and ceiling. That kind of noise is inevitable to any machine that is not running abnormally slow.

The other sort of noise is the exhaust and on that question it is interesting to note that the exhaust noise can be eliminated quite as completely as on the high class automobile and by the same kind of means. However, when it is necessary to completely eliminate noise to that extent on an oil-engine exhaust, it must be understood that a little back pressure is developed on the engine. Back pressure means a certain loss

in capacity. So that when required to run with absolute noiselessness of the exhaust, some allowance must be made on the rating, as the cost of the silence, but it can be done and quite as effectively, as it is done on a high-class automobile.

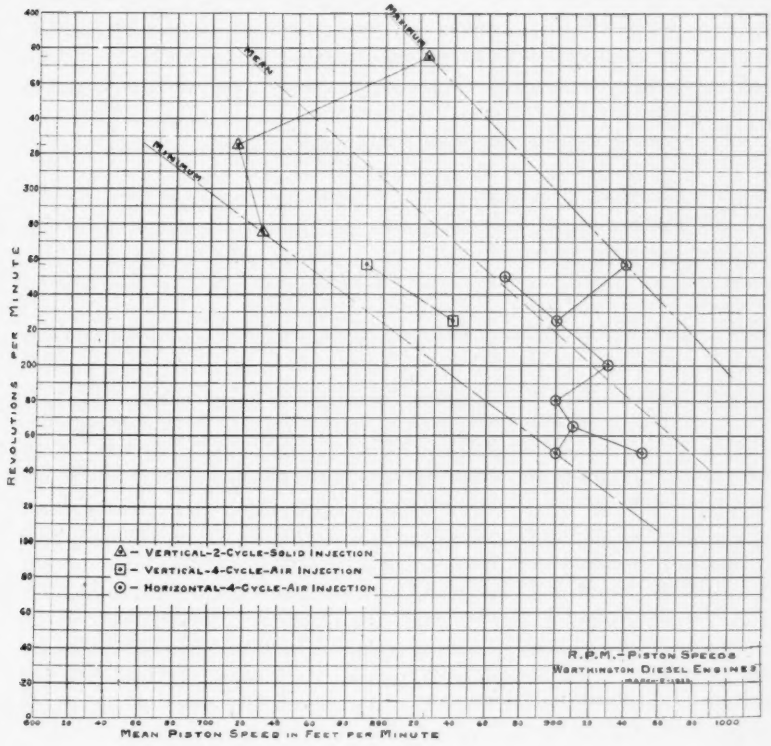

FIG. 3.

At this point it becomes desirable to get down to the matter of the pump relationship to the engine. To make this situation clear and concrete, it is necessary to consider definite machines and the Worthington product is selected. The Worthington oil engines are built in three styles, horizontal and vertical air injection, four-cycle — two styles — and the vertical two-cycle solid injection, the third style. The sizes range from 30 h.p. in 1 cylinder to about 1 100 h.p. in six cylinders and the three lines of sizes are all shown in the chart, Fig. 2. Worthington Diesel Engine Sizes and Speeds. The vertical distances represent the revolutions per minute, the spots represent, each one of them, an actual engine size, the radiating lines through the origin to each of the engine spots indicate what would happen to the horsepower, if the speeds were lowered or raised to

adapt the engine to a particular pump. This chart must be considered in connection with another chart. Fig. 3, Worthington Diesel Engine Sizes, Piston Speeds and r.p.m. which is important when one considers the problem of connecting the engine to the pump, especially a displacement pump. This chart shows the piston speed of the engine horizontally and the r.p.m. vertically. An inclined line has been drawn through the lowest, another one through the highest piston speeds, and a mean line drawn midway to show the general average of practice in the whole line of engines as to the relation of piston speed to r.p.m.

The connection itself, engine to pump, may be direct or it may be by gears, and if one examines the matter closely, it will appear that whether direct connection is feasible or not, depends upon speeds. Speeds will tell just which ones can be directly connected and which cannot, both displacement pumps and centrifugal or screw pumps. It will appear that the great bulk of these pumps cannot be directly connected because it is an accident to find the pump characteristic speed just right for the engine characteristic speed. Therefore, the great majority of this work requires gears.

Gear work falls into two classes, first, the gear down; second, the gear up. Gearing down to lower speeds is no problem, that is an old practice and there are hundreds of such pumps working on all sorts of service. They are typical, for instance, of the oil-pipe-line-pump practice of the West. The gear down is characteristic of the displacement pump and there is available a considerable number of pumps of different types today for gear connection to each one of these engines to absorb its horsepower at different heads and with a correspondingly variable g.p.m. On the gear up, with the centrifugal pump we find this situation: That the experience with steam turbine gears is directly applicable and we can use absolutely the same style of self-contained automatic lubricating gear box that was developed for the other practice, but of course with a different gear ratio. Applying reasonable gear ratios and not going at all beyond the range of proved practice of gear teaching, this range of Diesel oil engine sizes can be used to drive practically the whole line of standardized centrifugal pumps, giving a centrifugal pump for any head within reason and a corresponding g.p.m. to absorb the power of each engine. In the case of the screw pump, which of course it is understood is beautifully adapted to low-head work, there is a little better condition as to direct connection, as speeds conform better, as will appear later, when pumps are considered in more detail.

Further consideration of the water-works and pump phases of this situation of Diesel oil engine use, will be given by three other speakers, each a specialist.

The first topic to be taken up here is the possibility of direct connection of the oil engine and a displacement pump so that r.p.m. or piston speed

will be the same for both pump and engine. This will be presented by three of my associates in the Worthington Organization, first, Mr. Rodney D. Hall, Mgr. of the Water Works Department, will present the case for the Direct Connection of Diesel Engines to Displacement Pumps of Equal R.P.M. or Piston Speed. He will be followed by Mr. H. M. Chase, Engineer of the Deane Works, Holyoke Mass., who will explain the situation with regard to Displacement Pumps Gear Driven By Diesel Engines At Reduced R.P.M. and by Mr. Max Spillmann on Centrifugal and Screw Pumps Driven by Diesel Engines, Direct Connected or Through Gears. Finally Mr. Hall will close with a general comparison of Steam and Diesel Water Works.

Direct Connection of Diesel Engines and Displacement Pumps.

BY RODNEY D. HALL.*

For many years I have been associated with the work of the Snow-Holly Works of the Worthington Corporation, located in Buffalo, N. Y., which has built for some thirty years steam reciprocating displacement pumping machinery in capacities of from three million to forty million gallons in twenty-four hours, in both horizontal and vertical types. Some twenty years ago the Snow horizontal steam cross-compound type of pumping engine was developed and it has given very successful service. When, later on, these works began building horizontal 4-cycle air-injection Diesel engines up to 600 h.p., the possibilities of making such engines into pumping engines were given considerable study, some of the results of which will be reported.

The subject at the present time is the reciprocating displacement pump, in types and sizes suitable for direct connection to Diesel engines. The drawing, Fig. 4, shows a Worthington horizontal twin 150 h.p., oil, engine-driven pumping engine of the opposed type, size 20 in. x $8\frac{1}{4}$ in. x 33 in. Each side of the unit has a 150 h.p., Diesel power cylinder attached to one end of each of the two main frames. At the opposite end of the frame is an outside center packed plunger water end of the same construction as our most modern steam pumping engine. This pump runs at 165 r.p.m. at rated capacity, a speed entirely feasible, as has been demonstrated by the Unaflow pumping engine. The Porter Avenue experimental pumping engine at Buffalo was operated successfully up to 200 r.p.m., and when it got down to 165 revolutions, it seemed as if it were running at a slow speed. There was no difficulty in handling the water at these speeds with the Decrow Unaflow pump valve, because the valve construction was such and the valve area sufficient, to keep the speed of the water within the limits of conservative water-works practice.

* Manager Water Works Department, Worthington Pump and Machinery Corp.

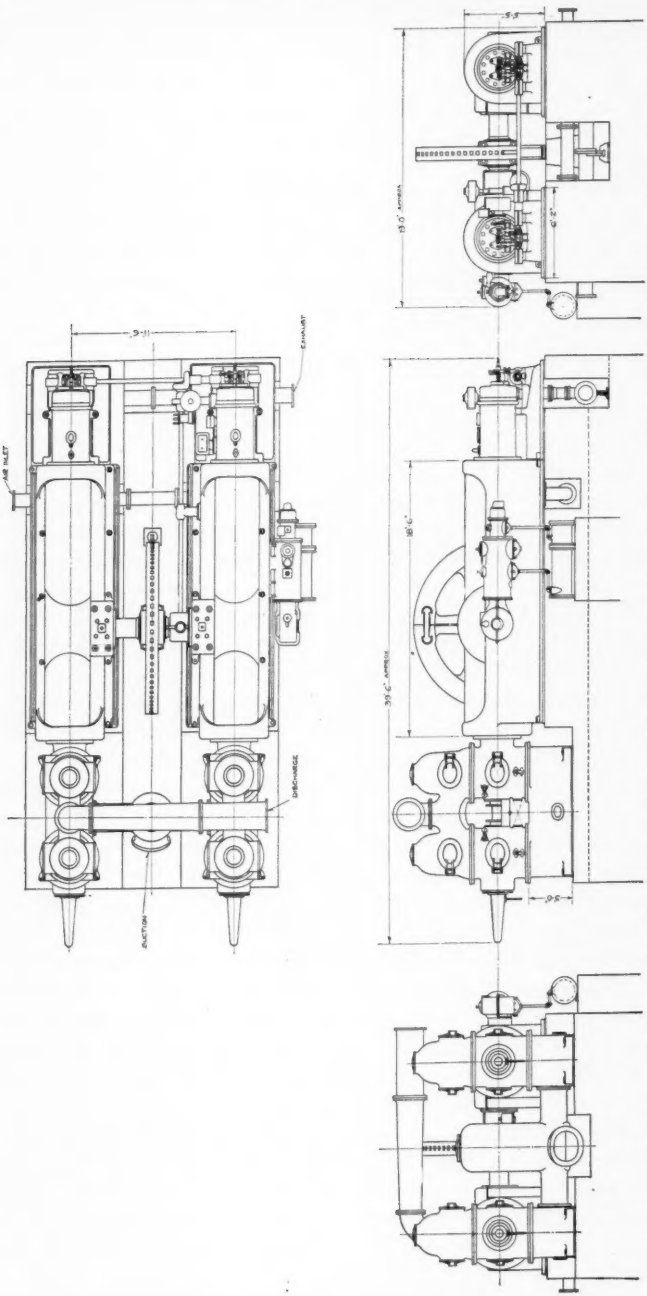

FIG. 4. — WORTHINGTON HORIZONTAL DIESEL ENGINES DIRECT CONNECTED TO DISPLACEMENTS PUMPS — OPPOSED ARRANGEMENT — SAME PISTON SPEED AND R.P.M.

In Fig. 5 there is shown another adaptation of a 150 h.p. single-cylinder Worthington horizontal Diesel oil engine connected by means of a crank to a displacement pumping engine having one double-acting plunger. The oil-engine prime mover has a 33-in. stroke; the pump that it drives has

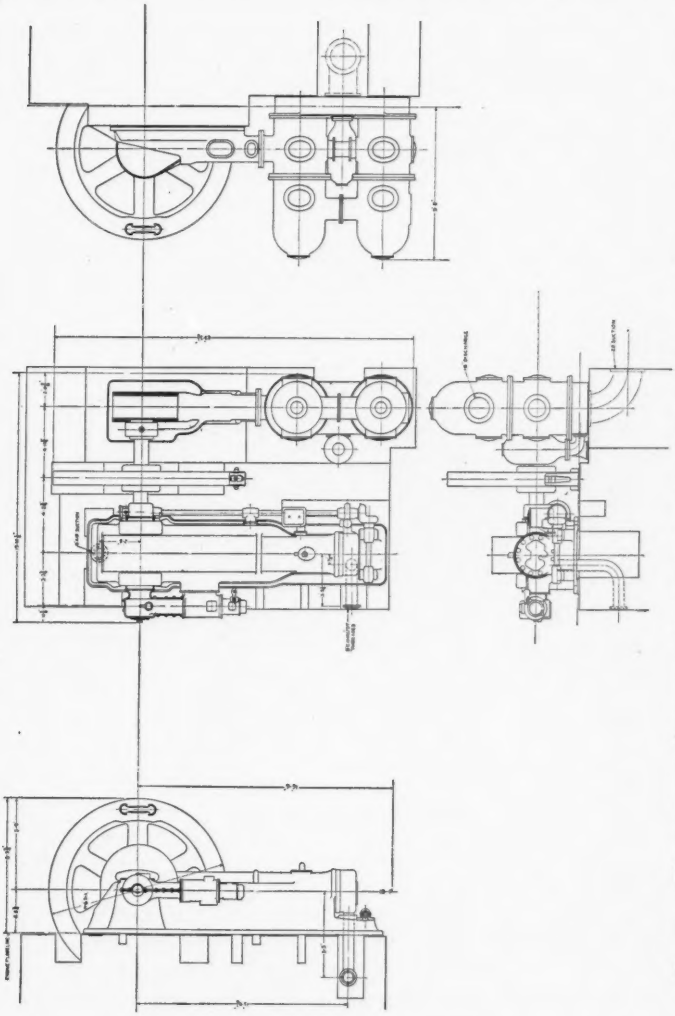

FIG. 5. — WORTHINGTON HORIZONTAL DIESEL ENGINE DIRECT CONNECTED TO DISPLACEMENT PUMP — TWIN ARRANGEMENT — SAME R.P.M. AND DIFFERENT PISTON SPEEDS.

a 21-in. stroke. The number of revolutions in each case is the same (165 r.p.m.) but the piston speed of the pump, due to its shorter stroke, is approximately 64 per cent. of the oil-engine piston speed. This 21-in.-stroke combination takes the same fluid end as the experimental Unaflow pumping engine which many of those present saw at Buffalo. There are

not many sizes and styles of oil engines that have suitable speeds for such direct connection to displacement water ends.

In water-works practice it is necessary to convert horsepower into terms of capacity and pressure, and, to make such conversion easy, the Chart Fig. 6 has been worked out. The limits shown by this chart are

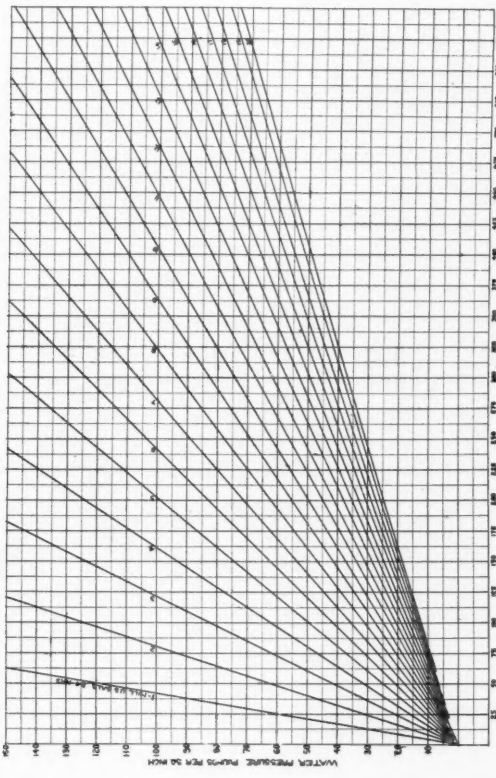

FIG. 6. — CONVERSION CHART — H.P., G.P.M. AND HEAD.

water pressures up to 150 lb. per sq. in. (as high as would be used in normal water-works practice), and horsepower up to 600, which would be a suitable water end load for a 750 h.p. engine. Six hundred useful water horsepower is also about the maximum point for reciprocating pump reduction gears. On water ends of the reciprocating type there are available developed designs up to 20 000 000 gal. capacity. By reference to the chart, it will be seen that 20 000 000 U. S. gal. of water in 24 hr. against approximately 74-lb. water pressure, is equivalent to 600 water h.p. All of the Snow-Holly standard water ends are strong enough for 150-lb. working pressure.

Displacement Pumps Gear Driven by Diesel Engines at Reduced R.P.M.

BY H. M. CHASE.*

The Diesel oil engine, at a fixed suitable speed for it, has but one variable, that is the horsepower, and any conditions that come within the horsepower capacity may be satisfied, providing that the proper selection is made of the pump. The pump must be selected to satisfy the two vari-

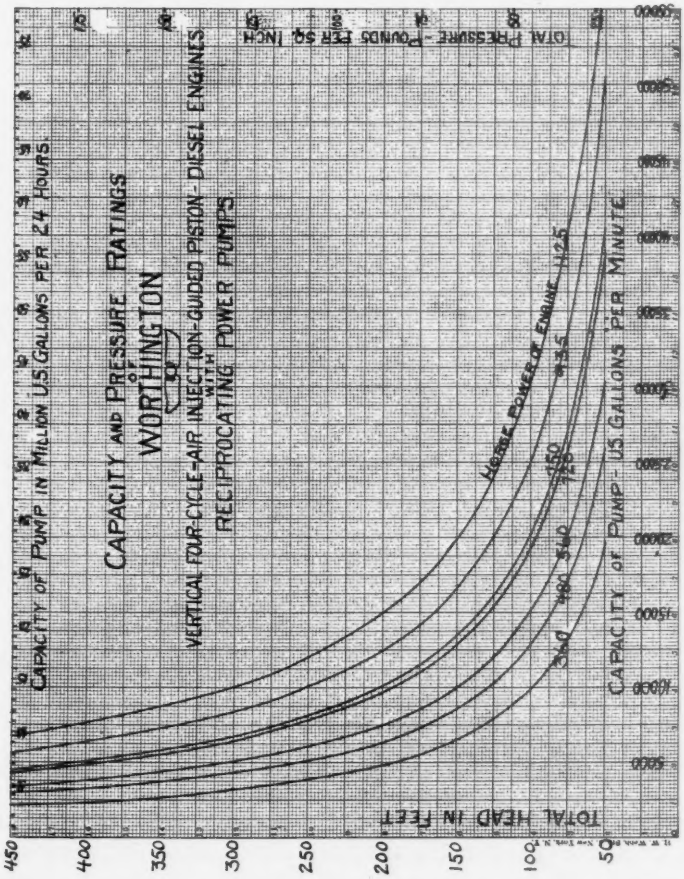

Fig. 7. — Displacement Pump G.P.M. and Head to Absorb the H.P. of Worthington Four-Cycle Air-Injection Diesel Engine.

ables of capacity and pressure, either of which may vary through a considerable range.

The accompanying charts, Figs. 7, 8 and 9, have been prepared to show pump g.p.m. and head to absorb the horsepower of each of the stand-

* Engineer Deane Works, Holyoke, Mass., Worthington Pump and Machinery Corporation.

ard sizes of Worthington Diesel Engines. Fig. 7 covers the range of the vertical four-cycle, air-injection type; Fig. 8 that of the vertical two-cycle solid-injection engines, and Fig. 9 the horizontal four-cycle, air-injection type. The curved lines represent the horsepower of engine and in the computations on which the charts are based, allowance has been made for the

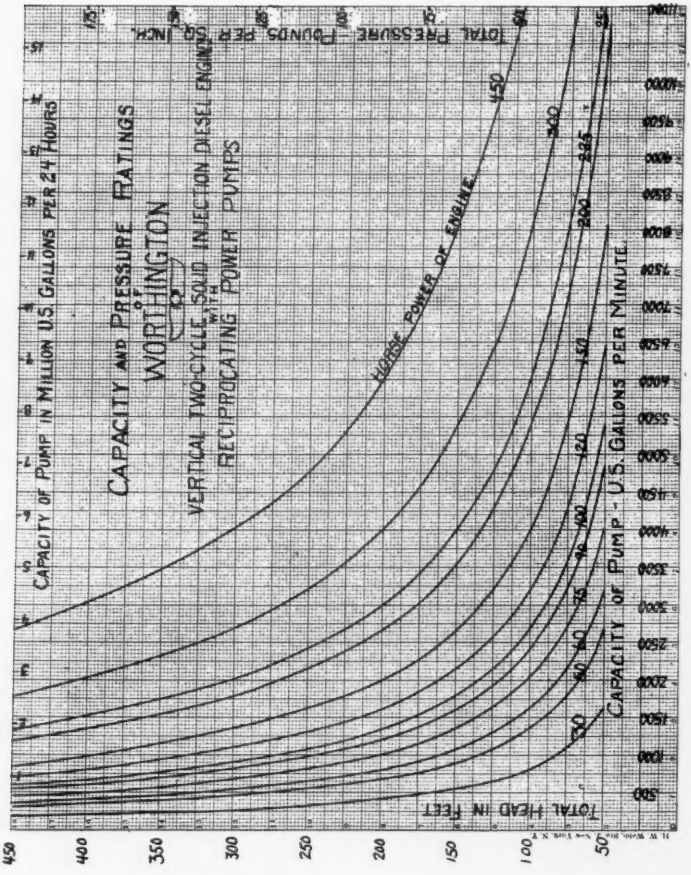

FIG. 8. — DISPLACEMENT PUMP G.P.M. AND HEAD TO ABSORB THE H.P. OF WORTHINGTON VERTICLE TWO-CYCLE, SOLID-INJECTION ENGINE.

efficiency of the pump at 85 per cent. and also allowance for operation of the engine at 80 per cent. of its rated horsepower, to allow ample margin for a change of conditions that may require power in excess of that anticipated.

The vertical lines on the chart represent capacity in gal. per min. or gal. per 24 hr., and the horizontal lines represent total head conditions in feet, or in lb. per sq. in. pressure. Thus, having determined the capa-

city required and the total head, including, of course, suction lift and pipe friction, against which it must be pumped, a direct reading on the chart will indicate the size of Worthington engine suitable for the service.

The charts indicate the wide range of conditions that can be met economically by standard Diesel oil engines. At 100 lb. pressure there are

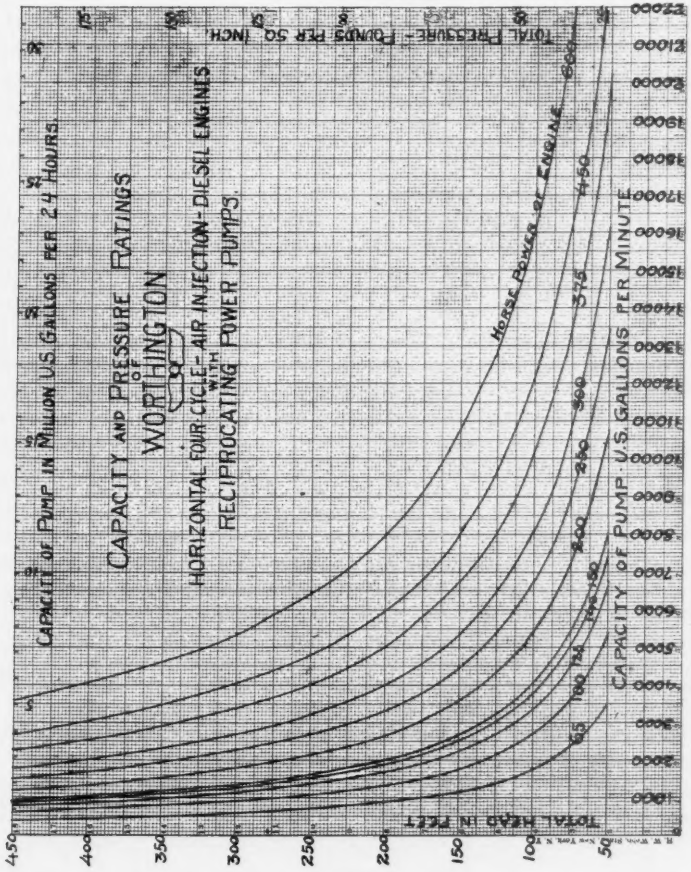
CAPACITY AND PRESSURE RATINGS
OF
WORTHINGTON
HORIZONTAL FOUR-CYCLE-AIR INJECTION-DIESEL ENGINES
WITH
RECIPROCATING POWER PUMPS.
CAPACITY OF PUMP IN MILLION U.S. GALLONS PER 24 HOURS.
TOTAL PRESSURE - POUNDS PER SQ. INCH
HORSE POWER OF ENGINE
CAPACITY OF PUMP U.S. GALLONS PER MINUTE
TOTAL HEAD IN FEET

FIG. 9. — DISPLACEMENT PUMP G.P.M. AND HEAD TO ABSORB THE H.P. OF WORTHINGTON HORIZONTAL FOUR-CYCLE, AIR-INJECTION DIESEL ENGINE.

engines suitable for capacities of half a million gallons to twenty million gallons per day, and at 200-lb. pressure there are engines good for anything between one quarter million to ten million gallons per day. Examination of the charts will show that for practically any combination of conditions within this range there is an engine that is the right size. It does not become necessary to select an engine too small or too large for the work in order to utilize manufacturers' patterns, because the Worthington standard oil-engine lines so completely cover the range of requirements.

The pumps now available for service in such an installation are of both the vertical and the horizontal type, selection between which will depend upon the local conditions. For the smaller capacity units the vertical triplex pump is usually selected. This type is available in any capacity from a 7 in. x 10 in. for one quarter million gallons per 24 hours, to a 16 in. x 16 in. for three million gallons.

Sixteen complete power ends 10, 12, 14 and 16-in. stroke for net plunger loads from 4 000 lb. to 36 000 lb., and an almost limitless number of water ends suitable for combination therewith, permit the construction of a pump suitably proportioned for any combination of conditions within the range mentioned above for capacity, and for any pressure requirements of water-works service.

The speed of the vertical triplex pump usually lies between 35 and 60 r.p.m. of the crank shaft, and between 60 and 120 ft. per min. plunger travel. The Diesel engine speeds vary between 150 and 375 r.p.m. Thus the maximum variation between speed of engine and speed of pump will not exceed a ratio of about 10 to 1. A single reduction of standard type spur or herringbone gears will meet any of the requirements at a rim speed capable of quiet operation. Such pumps, whether driven by belt, water wheel, electric motor, or engine, have at least one reduction of gears between the crank shaft and the jack shaft. The Diesel engine drive, therefore, introduces no complications. A set of gears is selected which will give the crank shaft of pump the proper speed, and give the jack shaft a speed the same as that of the engine. Connection between engine shaft and jack shaft of pump is made by means of a flexible coupling, or a friction cut-off coupling. In any case the pump is provided with a by-pass between the discharge and suction allowing release of the water load when starting. The engine will readily start with the friction load of the engine and pump as is required where a flexible coupling is used, but if it is necessary for special conditions to eliminate the load due to friction of the pump when starting, the friction cut-off coupling may be used.

One of these, a vertical triplex pump of approximately one half million gallons capacity, is shown in Fig. 10, driven by a 40 h.p. single cylinder vertical two-cycle solid-injection Diesel engine. Another one of larger size, 16 in. x 14 in. of four million gallons capacity is shown in Fig. 11 driven by a 150 h.p. two-cylinder vertical engine of the two-cycle, solid-injection type.

For still larger capacity requirements the horizontal type of pump either duplex or triplex, is better adapted on account of its greater stability, and the permissible elevation of the jack shaft being such as to allow a common foundation level for pump and engine.

The pumps are built in a great variety of patterns of 12-18-24 and 36-in-stroke and operated at a speed from 25 to 50 r.p.m. of crank shaft giving a very moderate plunger speed of from 80 to 300 ft. per min. Here too the relative speeds of engine and pump are such as to allow a single reduc-

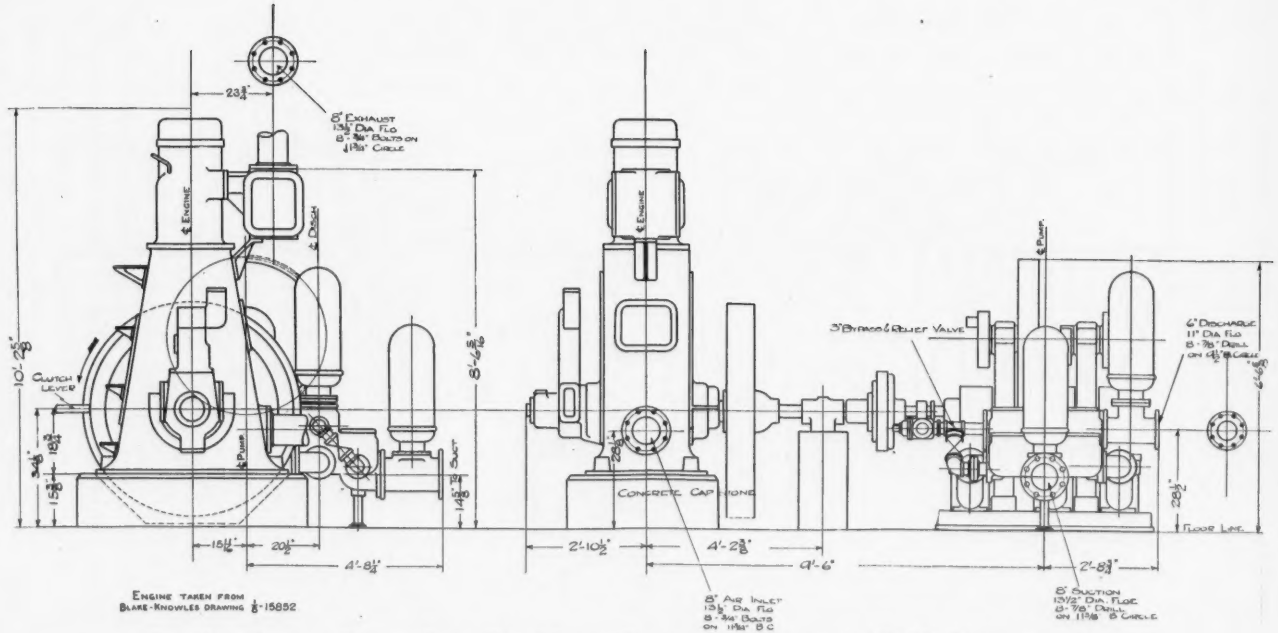

FIG. 10. — VERTICAL TRIPLEX PUMP, HALF MILLION GALLONS, GEAR DRIVEN BY 40-H.P. WORTHINGTON VERTICAL SOLID-INJECTION TWO-CYCLE OIL ENGINE.

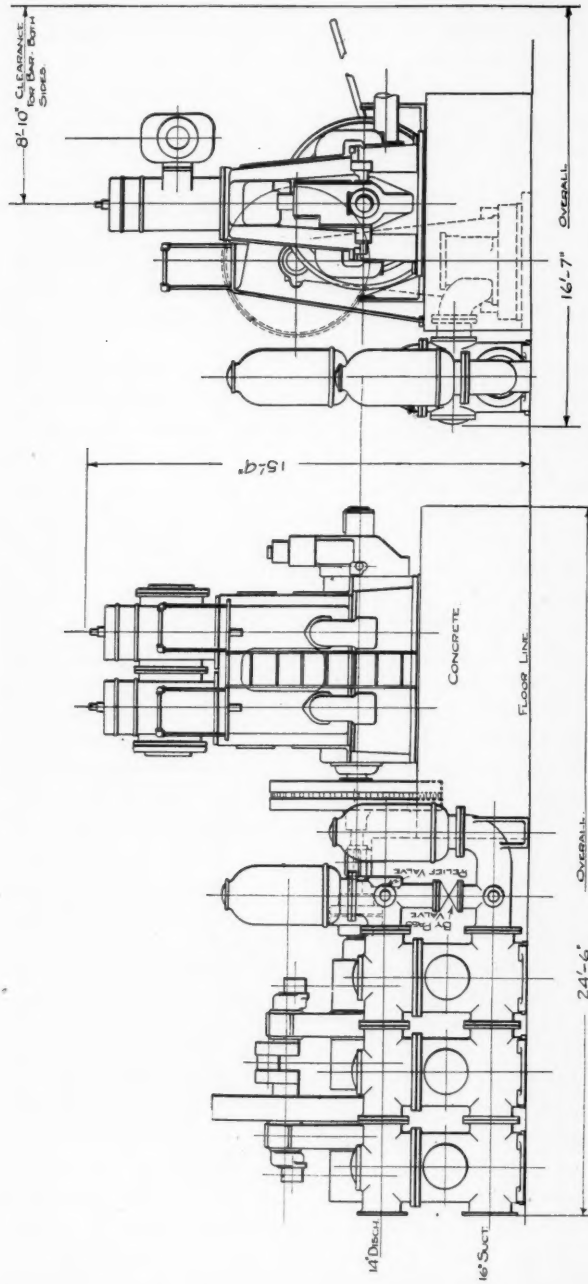

FIG. 11. — VERTICAL TRIPLEX PUMP, FOUR MILLION GALLONS, GEAR DRIVEN BY 150-H.P. VERTICAL SOLID-INJECTION, TWO-CYCLE WORTHINGTON OIL ENGINE.

tion of spur or herringbone gears, and connection by means of a flexible coupling or friction clutch. Sizes from 6 x 12 duplex having a capacity of one-third of a million gallons per day, up to a 21 x 36 triplex giving twenty million gallons per day are available from existing patterns, and the variety

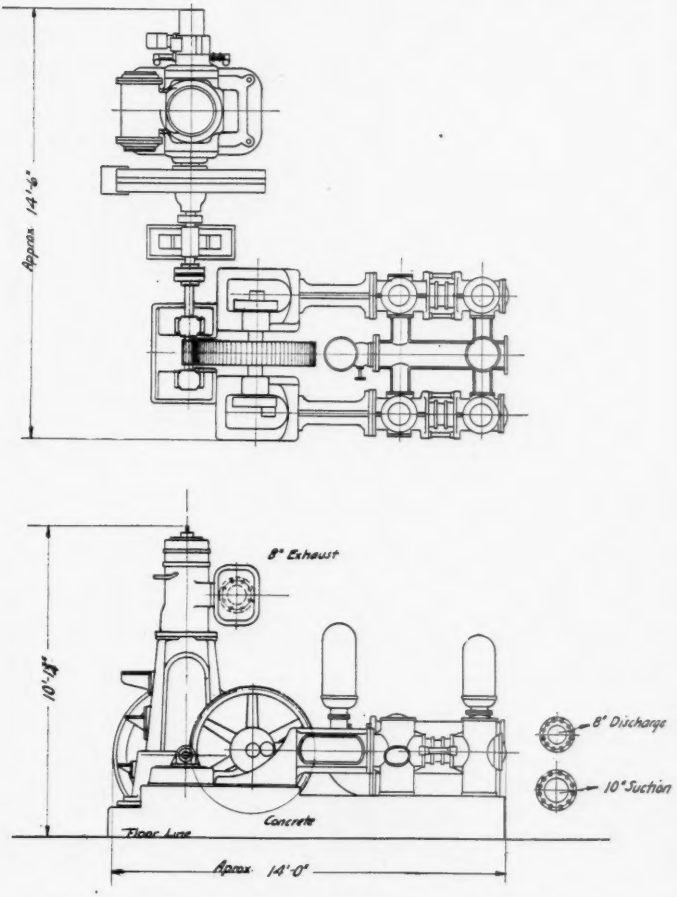

FIG. 12. — HORIZONTAL DUPLEX PUMP, HALF MILLION GALLONS, DRIVEN BY 50-H.P. VERTICAL WORTHINGTON TWO-CYCLE, SOLID-INJECTION OIL ENGINE.

of power ends and water ends permit of combination to produce a pump correctly proportioned for any conditions of services within the above limits.

Typical arrangements of such units are shown in the illustrations: Fig. 12 shows an 8 in. x 12 in. horizontal duplex pump of one-half million gallon capacity connected to a single cylinder 50 h.p. vertical two-cycle,

solid-injection Diesel Engine; Fig. 13 a 14-in. x 18 in. horizontal duplex pump of three million gallon capacity, driven by a 150 h.p. two-cylinder vertical two-cycle, solid-injection Diesel Engine; Fig. 14 a 15 in. x 36 in.

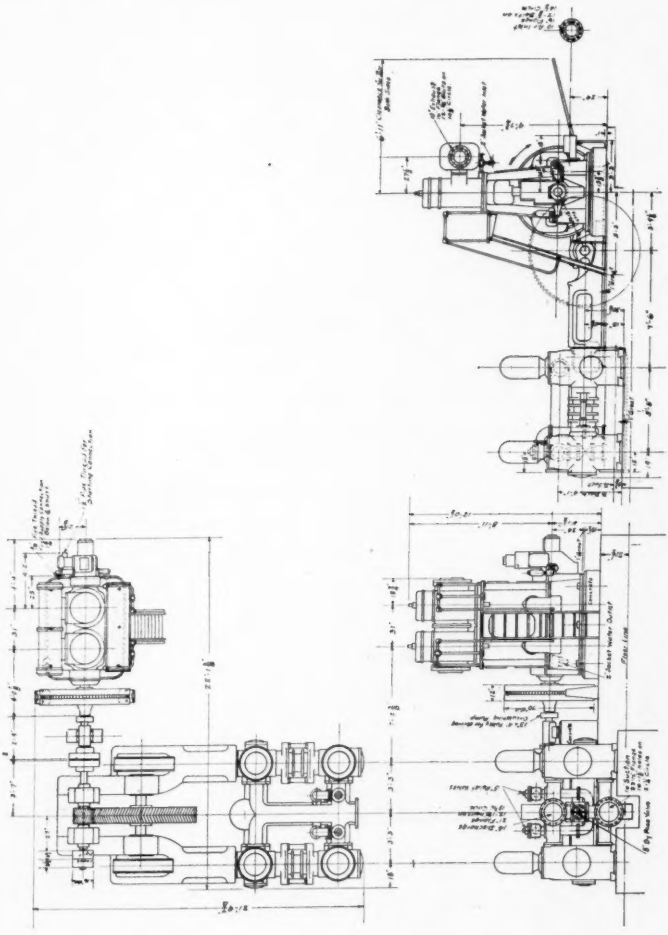

FIG. 13. — HORIZONTAL DUPLEX PUMP, THREE MILLION GALLONS, GEAR DRIVEN BY 150-H.P. WORTHINGTON OIL ENGINE.

horizontal triplex pump of ten million gallons capacity, driven by a 750 h.p. four-cyclinder vertical four-cycle air-injection engine.

The cuts show clearly the compactness and simplicity of the complete plant which is a feature of this type of installation.

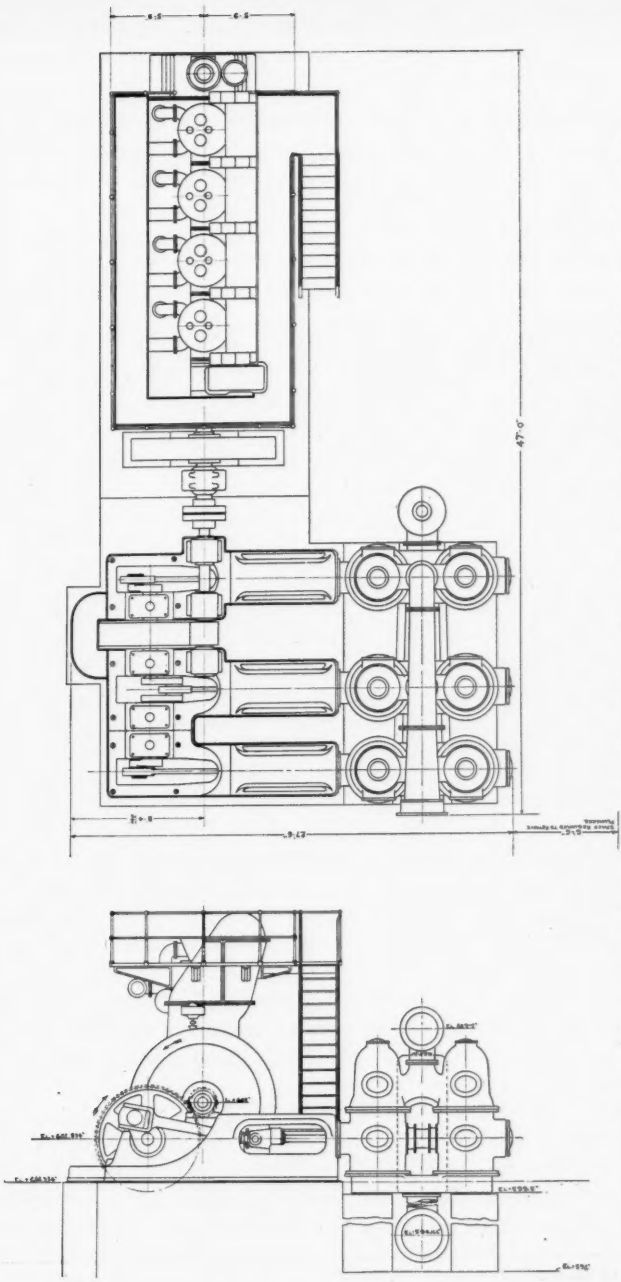

FIG. 14. — HORIZONTAL TRIPLEX PUMP, TEN MILLION GALLONS, GEAR DRIVEN BY 750-H.P. WORTHINGTON OIL ENGINE, FOUR-CYCLE AIR INJECTION.

Centrifugal Pumps for Diesel Engine Drive.

BY MAX SPILLMANN.*

The limitations of the centrifugal pump to raise water economically are chiefly governed by the available speed, revolutions per minute. Such speeds as the commercial Diesel engine develops are suitable for pumping against low and medium heads within certain limits of capacity.

To obtain higher working pressures, several means are available.

1. To operate several single-stage pumps in series, at engine speeds.
2. To interpose between driving engine and pump a speed-increasing gear.
3. A combination of the two above methods.

The final selection must be directed toward obtaining maximum efficiency, minimum of floor space and minimum of investment.

The modern herringbone gear can be successfully used for a speed ratio of 1: $5\frac{1}{2}$ in single reduction. This brings within the range of Diesel engine drive the complete line of standard centrifugal pumps designed for alternating current motor drive with speeds of 1 800 r.p.m., 1 200 r.p.m., 900 r.p.m., etc.

For low and medium heads it is possible either to drive direct by using the low-speed type of pump formerly developed for steam-engine drive, or to select a high speed-pump with speed-increasing gear.

When the pumping heads are very low, 3 ft. to 15 ft., it is often found that the Diesel engine speeds are too high for direct connection to the centrifugal pump. For such conditions the screw pump takes its place. By careful study of the problem, this type of pump has reached a development where its efficiency is equal and even superior to the centrifugal type.

To illustrate the foregoing, three curves, E-4017, 4018 and 4019, Figs. 15, 16 and 17, have been prepared showing centrifugal pump and engine sizes for working heads between 5 ft. and 500 ft., and capacities within the horsepower range of the respective Diesel engines.

For example, assuming a pumping condition of 1 800 g.p.m. against 140 ft. head, curve Fig. 4019 leads to the selection of an 8-in. single-stage pump driven by a 100 h.p. engine whose normal speed is 325 r.p.m., the pump speed is 1 450 r.p.m., pump efficiency 76 per cent. and gear efficiency $98\frac{1}{2}$ per cent. In many cases a great number of alternates may be made not shown on these curves, which only include pumps such as are commonly carried in stock.

Direct connection is suitable for heads from 30 ft. with minimum size engine (30 h.p.) to heads of 75 ft. with large size engine (450 h.p.) without resorting to multi-stage pumps.

Unless a special non-overload governor is provided for, centrifugal pumps should be selected with such characteristics that the driving engine

* Works Engineer, Worthington Works, Harrison, N. J., Worthington P. & M. Corporation.

cannot be overloaded at constant speed when the pump is working over a range of head as may be met in service. The pump design, therefore, does not in any way differ from the one which is selected in alternating current-induction motor drive. When a gear is used it will be mounted on a

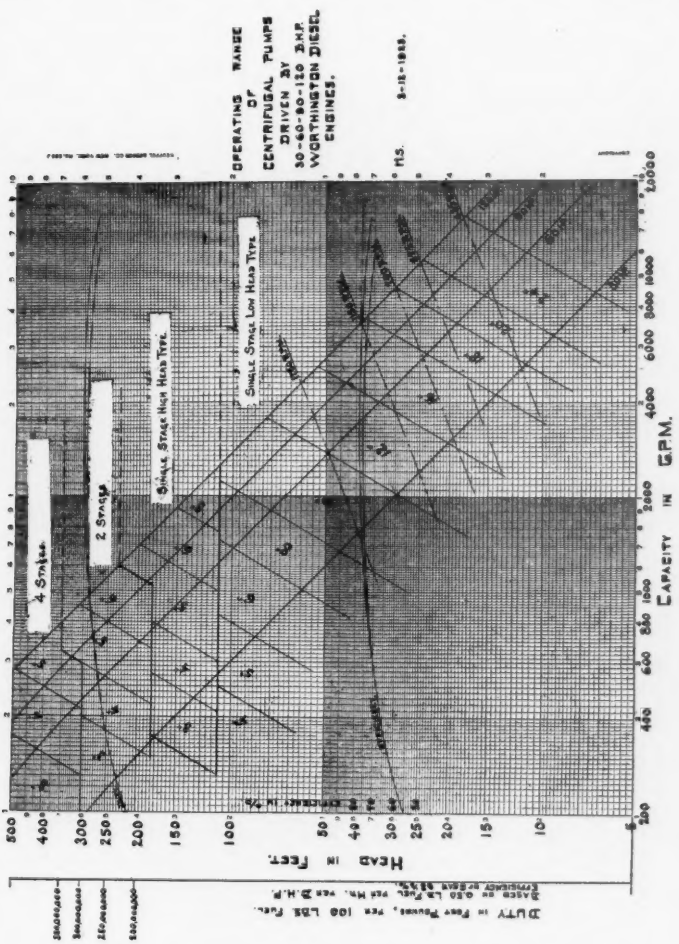
OPERATING RANGE OF CENTRIFUGAL PUMPS DRIVEN BY 30-60-90-120 B.H.P. WORTHINGTON DIESEL ENGINES.
Single Stage Low Head Type.
Single Stage High Head Type.
2 Stage
4 Stage
HEAD IN FEET.
CAPACITY IN G.P.M.

FIG. 15.

common base plate with the pump. Flexible couplings are essential with gear drive. For direct drive either rigid or flexible couplings may be used.

Valuable experience has been gained during the last few years in the design of speed-increasing gears. New gear-cutting machinery has been evolved and limits for allowable tooth pressure and pitch-line speed were

determined; also proper methods of automatic lubrication. As a consequence the product now available is as dependable as the engine and pump, and the noise which was observed in earlier designs has been suppressed.

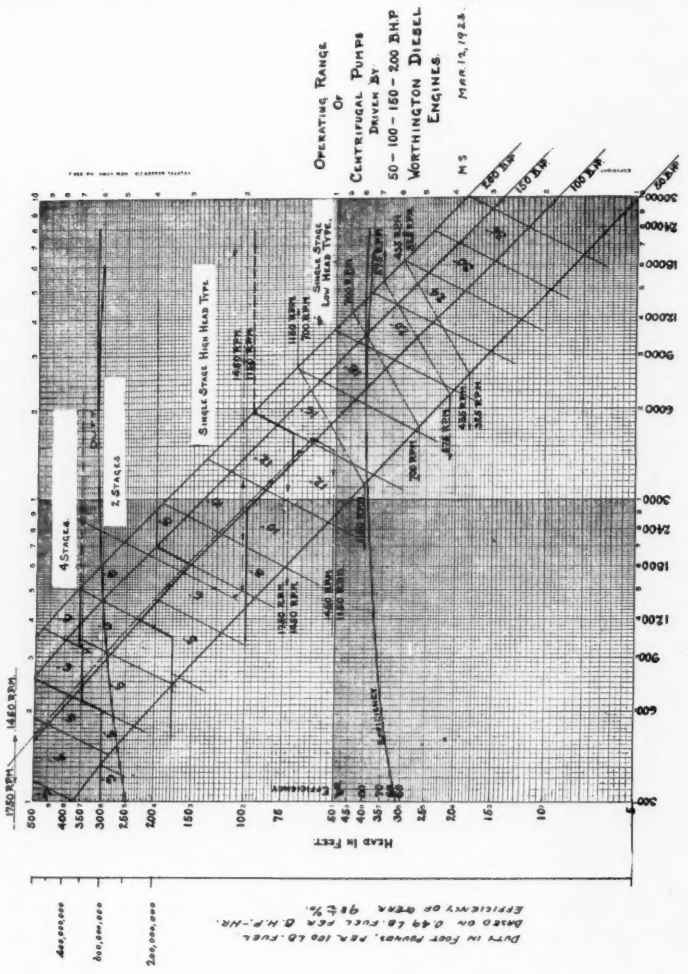
Operating Range Of Centrifugal Pumps Driven By 50 - 100 - 150 - 200 B.H.P. Worthington Diesel Engines.
Mar. 15, 1923
Single Stage High Head Type.
Single Stage Low Head Type.
4 Stages
2 Stages
1750 R.P.M.
1460 R.P.M.
Head in Feet
Efficiency
Duty in Foot Pounds per 100 Lb. Fuel
Based on 0.49 Lb. Fuel per B.H.P.-Hr.
Efficiency of Pump 98%.

FIG. 16.

In selecting gears consideration is given to the variation in torque resulting from the use of single or multiple cylinders and the flywheel effect of the engine.

The characteristics of the ordinary centrifugal pump are too well known to require any special mention here. It might be of interest here,

however, to give some data from a test of a Diesel engine screw pump which was recently obtained in the hydraulic laboratory of the Worthington Works at Harrison, N. J. This unit consisted of a 36-in. screw pump direct connected to a 75-h.p. single cylinder 275 r.p.m. Worthington Diesel

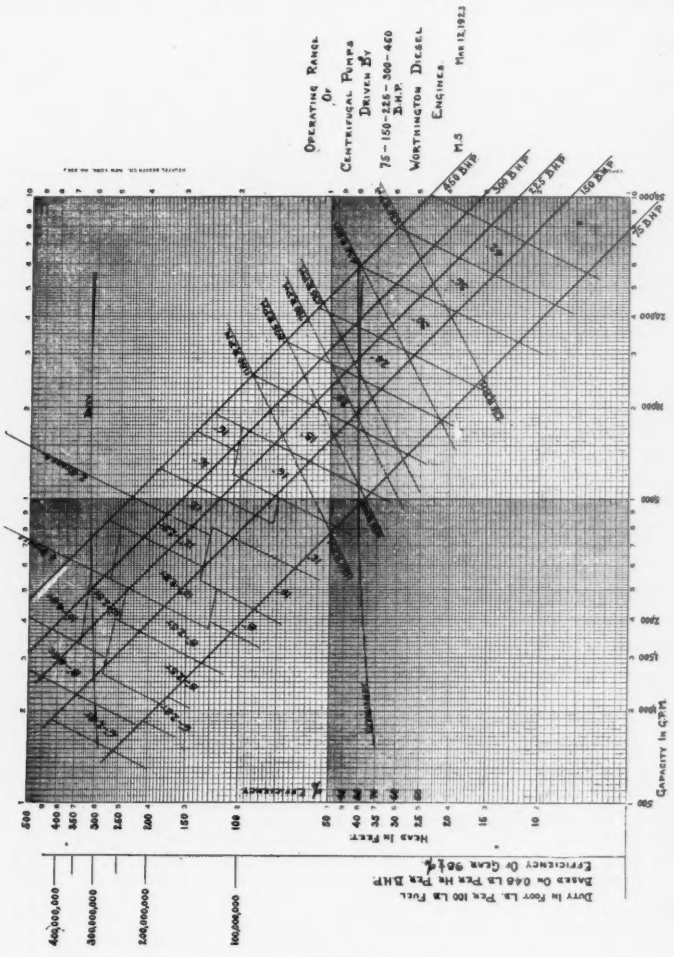
Operating Range Of Centrifugal Pumps Driven By 75 - 150 - 225 - 300 - 450 B.H.P. Worthington Diesel Engines
Mar 12, 1923
M.5
450 BHP
300 BHP
225 BHP
150 BHP
75 BHP
Capacity In G.P.M.
Head In Feet
Duty In Foot Lbs. Per 100 Lb. Fuel
Based On 0.48 Lb. Per Hr. Per BHP.
Efficiency Of Gear 96%

FIG. 17.

engine. It was to deliver an average capacity of 22 600 g.p.m. against $7\frac{1}{2}$-ft. head with a pump efficiency of $72\frac{1}{2}$ per cent. and an oil consumption of $31\frac{1}{2}$ lb. per hour. Before testing the combined unit the engine was tested with a water brake and the pump with a calibrated electric motor. Both pump and engine easily met their guarantees. The test of the com-

bined unit was of 72-hr. duration, during which observations were made of capacity, head, revolutions per minute and total fuel used.

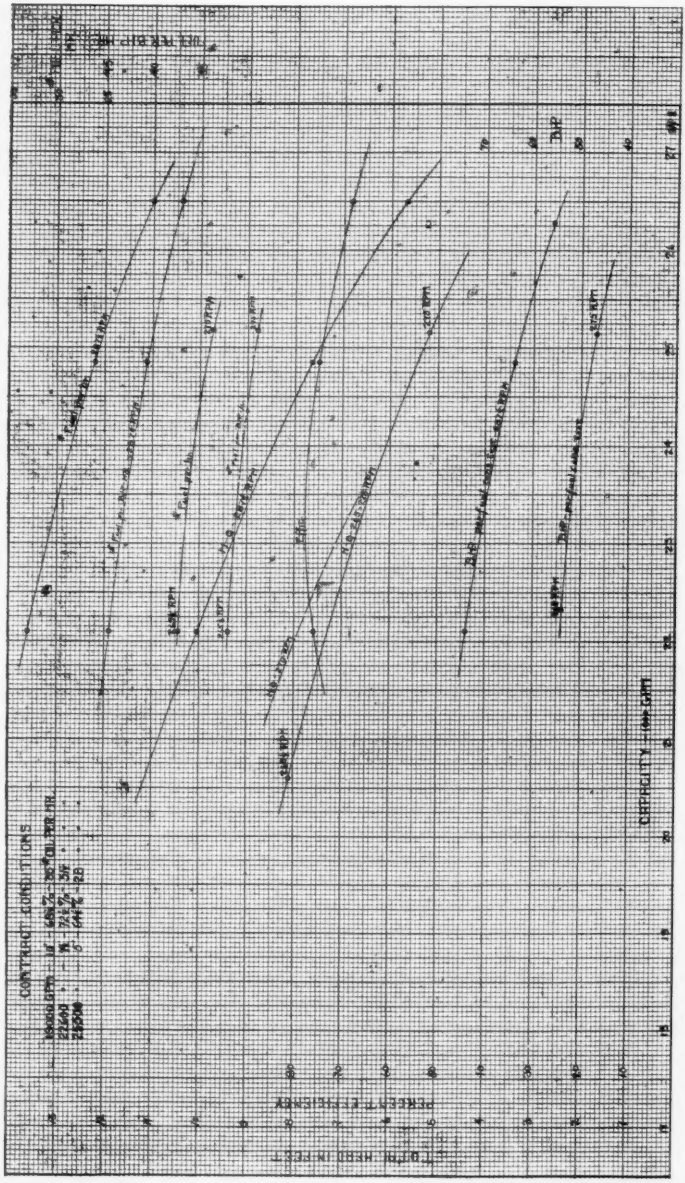

FIG. 18. — TEST OF WORTHINGTON 36" SCREW PUMP DIRECT CONNECTED TO SINGLE-CYLINDER WORTHINGTON DIESEL ENGINE.

The attached curves, Fig. 18, give the results at different speeds and clearly show the remarkable economy obtained both with the engine and pump, which in itself is so extremely simple an installation, as shown in Fig. 19. Some additional pumps and Worthington Diesel two-cycle

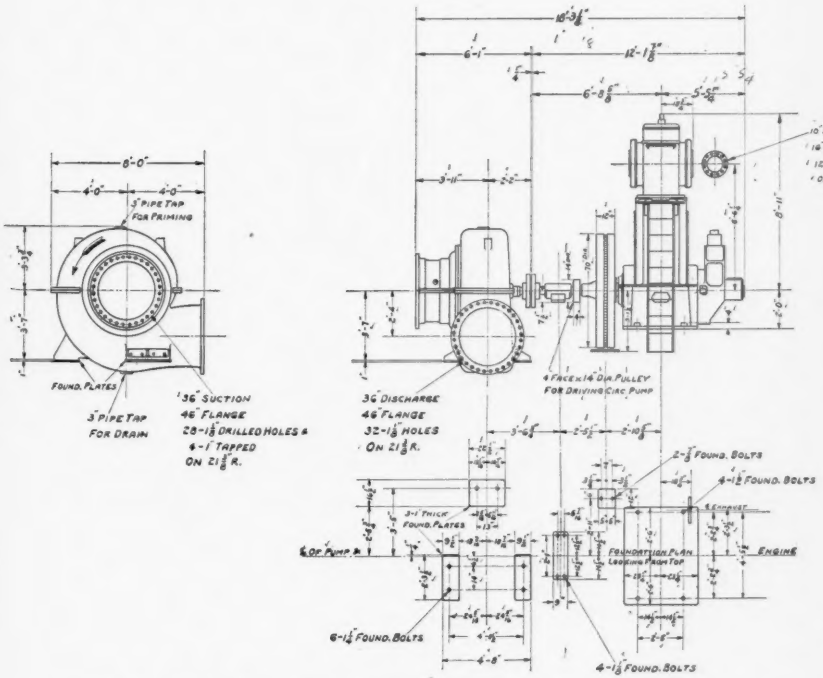
6'-0"
4'-0"
4'-0"
3" PIPE TAP FOR PRIMING
FOUND. PLATES
3" PIPE TAP FOR DRAIN
36" SUCTION 46" FLANGE 28-1⅛" DRILLED HOLES & 4-1" TAPPED ON 21⅛" B.C.
36" DISCHARGE 46" FLANGE 32-1⅛" HOLES ON 21⅛" B.C.
10" EXHAUST 16" FLANGE 12-⅞" BOLTS ON 14½" B.C.
4 FACE x 16" DIA. PULLEY FOR DRIVING CIAC PUMP
2-⅞" FOUND. BOLTS
4-1½" FOUND. BOLTS
3-1" THICK FOUND. PLATES
FOUNDATION PLAN LOOKING FROM TOP
ENGINE
6-1½" FOUND. BOLTS
4-1⅛" FOUND. BOLTS

FIG. 19. — WORTHINGTON SCREW PUMP 36" DIRECT CONNECTED TO SINGLE-CYLINDER WORTHINGTON OIL ENGINE.

solid-injection vertical engines are shown in Figs. 20-23. The first of these, Fig. 20, shows a two-cylinder engine direct connected to a 48-in. screw pump; Fig. 21, a three-cylinder engine gear connected to a 72-in. screw pump; Fig. 22, a four-cylinder engine gear connected to an 80-in. screw pump; and Fig. 23, a four-cylinder 300 h.p. engine gear connected to a three-stage, single-suction Jeansville Worthington centrifugal pump.

Due to its low starting torque, the Diesel engine-driven centrifugal pump is always ready for service and requires no clutch couplings or similar devices for starting.

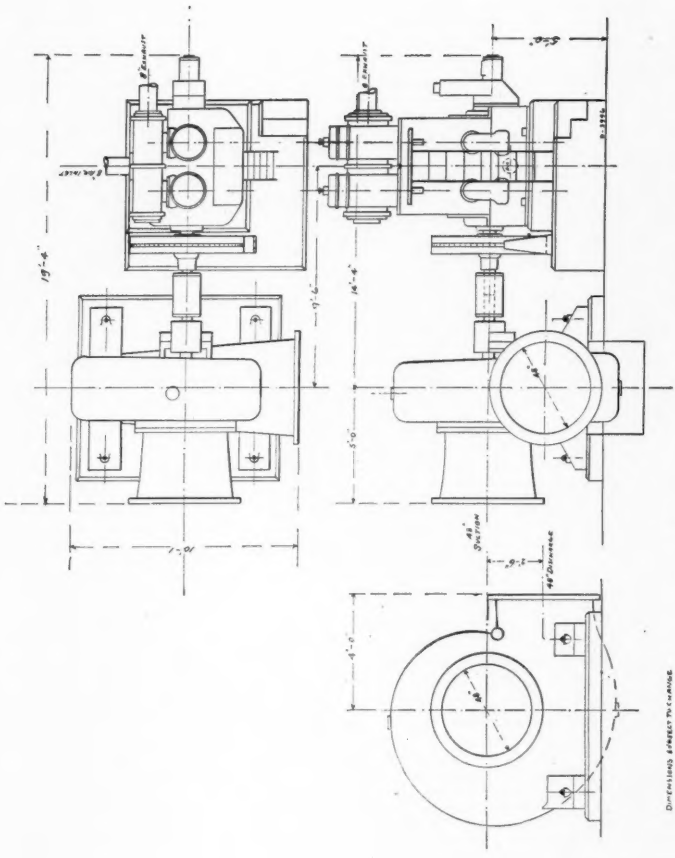

FIG. 20. — TWO-CYLINDER WORTHINGTON OIL ENGINE DRIVING 48" SCREW PUMP.

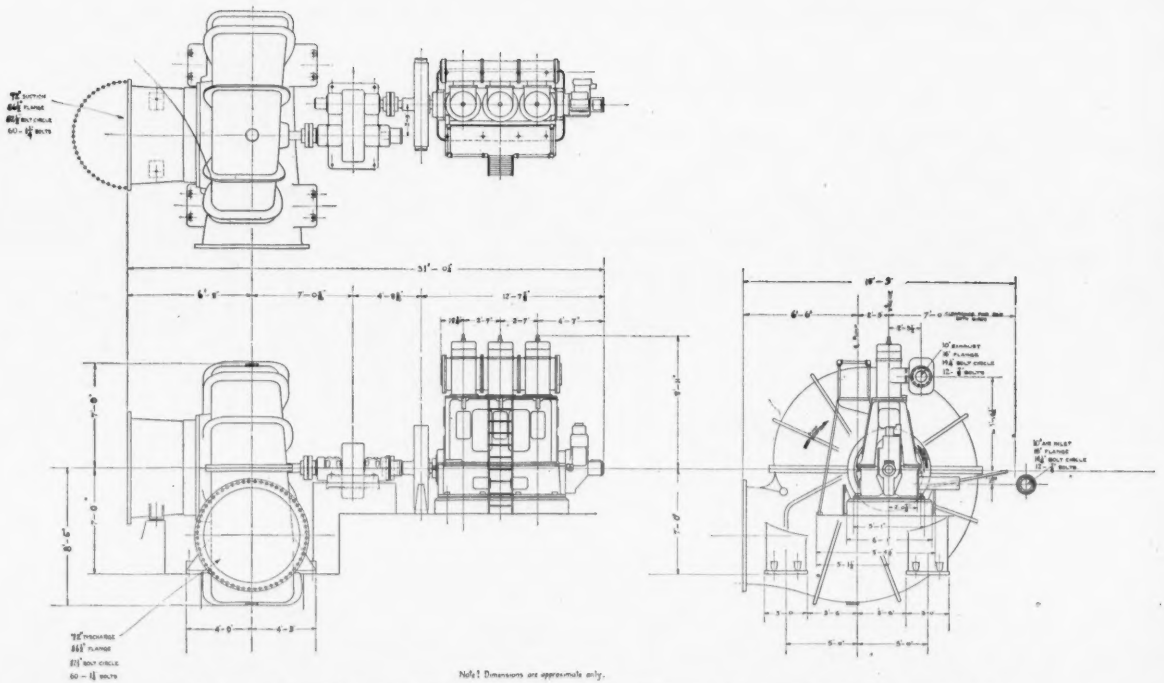

FIG. 21. — THREE-CYLINDER WORTHINGTON DIESEL ENGINE, GEAR DRIVING 72" SCREW PUMP.

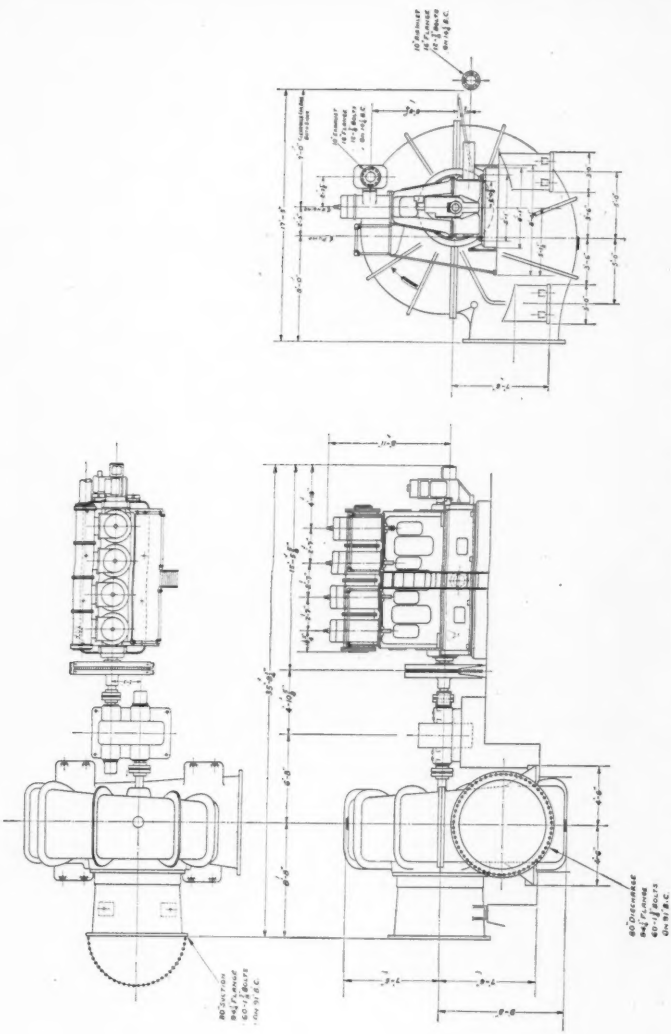

FIG. 22. — GEAR DRIVEN 80" SCREW PUMP CONNECTED TO FOUR-CYLINDER WORTHINGTON OIL ENGINE.

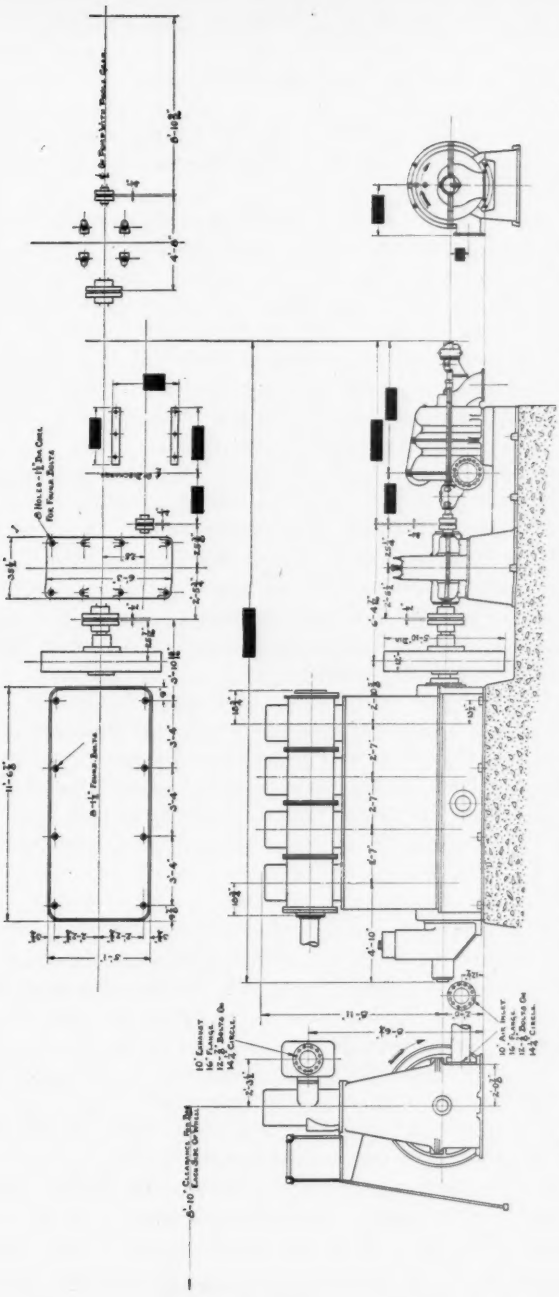

FIG. 23. — THREE-STAGE CENTRIFUGAL PUMP, SINGLE SUCTION, GEAR DRIVEN BY FOUR-CYLINDER WORTHINGTON DIESEL ENGINE.

Water Works Equipment — Steam vs. Oil Engine.

BY RODNEY M. HALL.*

Having been brought up a steam man, I am finding it necessary to more or less change my stripes to become a Diesel engine enthusiast, but I find that it is not at all a hard thing to do.

Twenty years ago, the usual competition in water-works equipment was between direct-acting duplex pumps and crank and flywheel pumps. Both types were usually considered on a comparative investment basis, and it was an open question when bids were received which of the two types would be the most advantageous for any given local conditions. As the years went by, it was a case of survival of the fittest, and the crank and the flywheel steam-driven pumping engine survived. Some direct-acting duplex pumps for water-works service are still built, but only a comparatively small number of such installations are made.

The same reasoning is properly applied to the Diesel engine development at the present time. In comparing Diesel equipment with steam, and in any consideration of new pumping equipment, Diesel oil engines must be included in the studies of various steam possibilities. It is not necessary or desirable to advocate any one type of pump, or drive, or source of power, because all types are now available and all are good. There are some locations where one type will prevail, in others a type of a different kind makes a more suitable installation.

In regard to the first cost, it is fair to presume, in fact it is so, that the Diesel engine-driven pumping engine runs into higher figures than steam-driven units, for the same capacity, when considering only the pumping machinery itself. However, the Diesel engine is a self-contained plant, whereas a complete steam plant must have its stack and boiler house, boilers, stokers, conveyors, heaters and other auxiliaries, in addition to the pumping engine. The gap of cost difference narrows, as a result, to such an extent as to make all classes competitive.

On the smaller units the Diesel pumping-engine first costs more nearly meet the initial costs of other types of pumping machinery than is the case on the larger installations. In fuel economy, the Diesel engine excels all other forms of pumping machinery, and the question, which becomes a local and a special consideration for each case, is how the two types compare in individual instances, considered as an investment. In a great many cases, if the Diesel engine is given the support which it deserves, and it is assumed that it is a safe unit and that it has come to stay, it will be found that on a dollars and cents basis, it fully justifies itself.

The height to which Diesel engine economy carries the "duty" of pumping engines is surprising. A fuel oil consumption of one half a pound per useful water horsepower hour is obtainable as an overall measure of

* Manager, Water Works Department, Worthington Pump and Machinery Corporation.

economy on these pumps and this is equivalent to a horsepower hour for a fuel consumption of approximately 9 250 b.t.u.'s. Translated into "duty," even the small Diesel engines give upwards of 200 000 000 duty per million b.t.u.'s. Every one knows the effort that has been made to reach 200 000 000 duty per 1 000 lb. of steam, and if we assume that the b.t.u. duty is 85 per cent. of the steam duty, which is an approximately correct factor, we have somewhere in the neighborhood of 170 000 000 b.t.u. duty for the *largest* steam reciprocating engine, having 110-in. L.P. steam cylinder, against upwards of 200 000 000 b.t.u. duty on a *small* Diesel engine-driven pumping unit. This point is of the utmost importance — the extraordinary high duty of small-sized Diesel engine units.

The time has surely come for users and engineers selecting pumping equipment to realize that it is to their great advantage to give the Diesel engine the utmost consideration. As we have said before, the Diesel engine is here to stay and the Worthington Company is here to stay. We stand behind the internal combustion product the same as we have always stood behind all our previous output in past years.

DISCUSSION.

THE CHAIRMAN. In the first place, the Chair wishes to thank Dr. Lucke for his assistance in developing this interesting subject. Now, all of these remarks will be published in the JOURNAL, in which form, of course, they will be much more available for your study and digestion. Still, I think one of the most interesting parts of our meeting can be obtained through a discussion, and now the subject will be thrown open to the membership for a discussion, and Dr. Lucke and these gentlemen who are with him I think will be very glad to answer any questions you may ask, and then I will ask Dr. Lucke to take five minutes to close the discussion.

The subject is now open to you for discussion.

MR. VERNON F. WEST.* Mr. Chairman, there is one matter that Dr. Lucke spoke about here on which I should like to have a little more information. In the East here, pumping stations as now constituted have the pumps practically operating under constant speed. That is due largely to the topography of the land, whereby we are able to get sufficient storage to run our pumps at a uniform speed all the time. That is, our run is practically 100 per cent., when it is not we shut down. In the Middle West, where the topography is not the same as with us, their pumps oftentimes are shut down so that they just turn over. That is with steam operation, resulting in inefficient performance.

Now, it is a question to my mind how that will be handled in the Diesel operation. That is, do you get economies in the operation of the

* Treasurer, Rensselaer Water Co., Ft. Rensselaer, N. Y.

Diesel engine at half load, three-quarter load, full load and a little overload, in comparison with the steam engine? I have heard some discussion on that, but I would like to have a little more information as to whether the steam engine is more economical in operating under varying loads than is the Diesel engine. The Diesel engine in a plant can be direct connected to the driven power through reduction or by some other method. But in the operation of a pumping station where the power is dispensed not only through the pumps but through the filtration plant and through other subsidiaries, do you want one Diesel engine, or do you want four or five of them?

The question, to my mind, is whether we had not better use Diesel engines to generate the power electrically and to distribute the power through the stations, than to have four or five Diesel engines each moving one or two pumps. It is a question, to my mind, how the Diesel operates on full load, half load, or other proportion of the load, in comparison with the steam engine.

DR. LUCKE. There are two parts to the answer. One is a matter of engineering facts concerning the engine characteristics, the other is a matter of engineering judgment as to what is the best use to make of those facts.

Now, as to the facts about the engine itself and the characteristics. It may be said that substantially the indicated thermal efficiency is constant at all loads. The efficiency on net output falls off with load reduction because of the substantial constancy of the mechanical losses in the engine. So that the best results in overall efficiency would be obtained by keeping the engine as nearly loaded as possible. That does not mean the same thing with the Diesel engine as with steam, because by using many small Diesel engines which can be started and stopped without warming up, each can take the load just as quick as the valves can be manipulated. It will not hurt the engine a particle to do that and it can be adjusted to its most efficient load without any reduction in efficiency by reason of the multiplicity, as would be the case with steam. Of course, there is a little added expense in using five engines in place of one, not so much on account of the engines as for building and foundations.

Another set of engineering facts is concerned with the speed characteristics of the engine. Operation at sea with the motor-ship engine direct coupled to the propeller is common down to 30 per cent. of normal speed, with such a moment of inertia as is characteristic of the rotating parts of the ordinary marine engine and there is practically no flywheel. So that if one wants to vary the speed of a Diesel engine through any given limit, down even to 15 per cent. of the maximum, it can be done if the requirement is known ahead of time and the necessary flywheel be put in. With the ordinary flywheel, from full to about half speed or one-third speed represents the speed range, depending upon the turning effort of the particular engine on the one hand and the flywheel weight on the other. This can be extended by adding to flywheel masses.

The suggestion was made about generating electric power and distributing it to electric motors. There is one interesting type of case that suggests itself, of which there are some actual examples, and that is general town service where electricity and water are both to be supplied by the town. That is the combined lighting plant and water works. Here it is possible to couple directly generators to each of the engines to operate the lighting service directly and to operate the pumps by motors. In fact, it is possible to distribute the pumps over the transmission line should that be desirable. There will be more of such stations, combined lighting and pumping stations, where the power is developed in the form of electricity directly.

Multiplicity of engines is desirable when there is a periodic fluctuation of load, not only to keep engines operating each at its best load, but for other reasons, bearing on assurance of continuity of service. It must be remembered that the Diesel engine is not only an engine but it is also a furnace, taking fuel into the cylinder and burning it, and therefore certain cleanliness conditions will require attention. What has been accomplished in clean combustion in cylinders is simply wonderful when the conditions are realized, but maintenance of absolute cleanliness of cylinders is impossible over long periods of time. The most minute deposits per minute may make quite a total over a year. Consider the deposits of scale in a boiler with water containing only an infinitesimal amount of solids per gallon. Yet an appreciable amount of scale will accumulate over a period of time. Exactly the same sort of situation exists in the cylinder of the internal-combustion engine. The exhaust may be absolutely colorless and combustion as nearly perfect as anybody can measure; the chemists may be unable to detect any waste products in the exhaust, nothing but carbon-dioxide, nitrogen and water vapor, and yet in time the interior parts will have to be cleaned, the piston rings, the sprayer and the valves. The valves, furthermore, will have to be reground on their seats. It does not take long and it does not have to be done often, but it does have to be done, just as surely as periodic internal cleaning of boilers is necessary.

Therefore, in a Diesel engine plant, provision must be made for periodic inspection, adjustment and cleaning, and if that is done, fine service will surely result. On the ships, this is done; not only the commercial Diesel cargo motor ships, but particularly the ships of the war, — the submarines were all engined with these machines and they gave a wonderful performance, so wonderful that at one time you remember the outcome of the war was very much in doubt. That kind of reliable performance was obtained by a fixed operating schedule, every so many days do this, every so many days do that. A little experience creates such an operating schedule. But to do this and to do that internally, requires that the engine be shut down five minutes or fifty minutes or two hours every once in so often. With multiplicity of units in a station, the ordinary fluctuation of load will give the operator a chance to do the necessary inspecting and

internal cleaning and valve grinding, per schedule. This is the ordinary proper care of an oil engine, which replaces the relining of furnaces, the cleaning of boiler tubes, and all that other work that goes with the steam equipment.

That is the second reason for multiplicity of Diesel units and smaller sizes, and such multiplicity of units does not result in any loss of efficiency with the Diesel engine, which is not true with steam.

MR. FRANK A. MARSTON.* In thinking of this subject in its general details rather than in the analysis of any specific problem, it is of interest to have figures, some round numbers, such as we have in steam practice, for the performance of such an engine.

I would like to ask the question as to what sort of round number would it be safe to have for the fuel consumption of such an engine, or whatever equivalent basis or unit may be in frequent use? Some unit of that kind would be quite helpful, not in analyzing any one specific problem but just in a general consideration of the subject.

Also, in round numbers, an outside figure of what these engines cost per horsepower, approximately, or any other similar unit which is convenient in checking?

DR. LUCKE. The fuel consumption is usually based on a calorific power of oil of 18 000 b.t.u.'s per lb. Most oils are better than that. But there is not very much variation in the calorific power per lb. of oil for quite a wide range in physical properties. It is surprising how constant the calorific power is. On the 18 500 b.t.u.'s per lb. basis, the minimum is about .43, the maximum about .50 lb. per brake h.p. hour. This covers the whole range, from a small two-cycle solid-injection engine at .5 lb. to a large four-cycle air-injection engine at .43 lb., which is not very much.

On the other question, of engine costs, the round numbers that are easy to keep in mind are $65 per h.p. for the smaller two-cycle, up to $75 or $80 per h.p. for the four-cycle engine, depending upon the number of cylinders. Next month, however, that might be different.

MR. SAMUEL A. AGNEW.† One thing that surprises me is the fact that the Doctor says we can reduce the running of these engines to 15 per cent. of their revolutions per minute. I am rather surprised at that. I have had to do with the old type of oil engine, the old H.A. type, and that is a solid-injection type of engine. Now, as you know, the cam operating on the cam shaft operates the oil pump which injects the oil into the machine. If that cam is not operating rapidly enough the oil will sort of slobber into the machine. Now then, unless that oil is sprayed in with force against the other side, you can readily see that you will not get a good combustion, that is, your oil will not vaporize properly. So that I am rather surprised to hear the Doctor say that we could run an engine at, say, 15 per cent. of its normal revolutions. I know I cannot do it with the old type engine.

* Metcalf & Eddy, Boston Mass.
† Superintendent Water Works, Scituate Mass.

DR. LUCKE. That is a perfectly good question and it indicates that "The world do move." Of course it can be done, but it must be known ahead of time what it is necessary to do and then the engine can be made to do it. If one wanted to run at the minimum speed, such a range of speed which is unusual, nobody has ever wanted to go that far, it would require many cylinders to give a reasonably uniform turning effort, as one can readily see. Then by adding a proper flywheel, the 15 per cent. of normal speed comes within reason and such operation will be assured.

As to what would happen with the fuel injection, it must be remembered that the kind of injection described by you would not do and it would not be used. Much has been learned about fuel injection and combustion since your old engine was designed, more than there is time to tell about here, and there are now all kinds of different schemes for injecting the fuel, some of which will do the job. It is a matter of design to meet almost any specifications.

MR. A. O. DOANE.* One of the prime requisites of pumping machinery, especially for municipal works, is reliability. I would put that ahead of economy if I were making a choice. I haven't heard much said on that feature.

There is another feature that is also of a great deal of importance in making a comparison of different types of pumping machinery, in making a choice as to what to install, and that is the relative life of the machinery.

I would like to have some information on those two points.

DR. LUCKE. On the matter of reliability, the motor ship was cited. For a long time no one in stationary practice, certainly no one in this country, was willing to take the oil engine seriously until that most amazing demonstration of the reliability of the motor ship at sea became recognized. One case from my own experience will serve as an illustration. I went down to the water front of New York one day with a party to visit a motor ship that had come in from Manila by way of the Panama Canal. She had been fifty-six days at sea and the engine had never stopped once, full load all the time. That was her regular experience. I have been told of ships, and the insurance and other records will confirm it, that motor ships sail regularly from British channel ports on the other side of the Atlantic to China ports without ever a stop or the loss of a revolution, then unload, reload, and come back. There is real reliability. Now these statements need not be believed on any man's word, they can easily be verified. Look up the records of the motor ships at sea. These records are more or less public property and can be had through Lloyds or the American Bureau of Shipping, and the various marine magazines. In that way any one will be bound to believe that a rightly made Diesel engine is a mighty reliable machine.

We have also some other demonstrations of reliability on land, one group of these happens to be with pumps, pumping oil in pipe lines in

* Division Engineer, Metropolitan District Commission.

the oil-producing sections of the country. I have been told that many pumps with oil-engine drives have operated 100 per cent. non-stop, for 80 per cent. or more of the year. That is pretty good reliability. The necessity for stops is a cleaning necessity more than anything else. They require a few hours every once in a while for cleaning, and a few hours at longer intervals for valve grinding.

With such facts, how can any one say there is no demonstration of reliability of Diesel engines, with so many motor ships at sea with lives depending on them and some millions of dollars of property carried almost around the whole world.

MR. AGNEW. Mr. Chairman, the gentleman asked about the matter of reliability. We started out with one small engine, in a small water company, so that we do not need to go to any one for a reliability test. It was a small works which was hardly able to pay a man to stay at the station all the time. That engine would be started in the morning, the station would be locked up, the engine would be left running to pump all day long. At night the man would go and oil up, and he would lock the station again, go off and leave it at night. In a run of one year I made one test. I checked the engine from February 1, of one year, to February 2, of the next year, and in that time made two stops to take up bearings, not in the engine but in the pump. So that as far as reliability is concerned, I do not see anything that has ever beaten it.

And another consideration is the cheapness. Economy of attendance. To me that is the one great consideration. Instead of having a number of men around to operate boilers and the engine, one man can take care of a number of those plants and do it very easily.

MR. FRANK A. BARBOUR.* I would like to ask Dr. Lucke whether there is any chance of the situation being altered by the increased use of heavy oils for heating houses, and so forth. Up here in New England this winter we have had rather a severe experience, and we hear that the Geological Survey advises against the use of heavy oils for some purposes. What is the possibility that the situation may change by the using up of the available oil supply?

DR. LUCKE. That is a good question. The oil business today is controlled by the automobile, and everything that is done to produce, refine and distribute petroleum and its products, all revolves about the demand for gasoline for automobiles. Nobody believes that that demand is going to lessen. Everybody believes that that is a stable and more or less regularly-increasing demand, certainly in this country. Now, roughly, not strictly accurate, but good enough for present purposes, for every gallon of gasoline made, there becomes available two gallons of fuel oil that a Diesel engine can burn, and it has got to be disposed of somewhere. The only question is, how? That oil is available. Just in proportion as regularity of use of such oil develops in any one section, so will the oil com-

* Consulting Engineer, Boston, Mass.

panies establish a supply or feeder system. They will provide the supply, they will provide the storage stations just as soon as there is any regular use of fuel oil, and statistics are available of where that has been done. The fear that the household user, or that the steam user, will rob Diesel engine users of that fuel, is unfounded because the economics of the situation is that as the users multiply, the tendency, of course, is for the price to go up in this as in any other commodity. That is natural enough. Then who gets it finally! The one who can afford to pay more and the one who is making the most efficient use of it. And so in that case, as the price of fuel oil goes up, the Diesel engine can afford to take it away from the steam boiler. That is just a natural fundamental and economic principle, especially when it is considered that the steam boiler can be operated on coal, and that coal is available in unlimited amounts.

As to the future supply of petroleum from which to make the gasoline or its fuel oil by-product, it is true that geologists have predicted the end of the world in petroleum, but from personal observation for over twenty-five years they have been predicting the same thing. Most of their predictions have been wrong and they are likely to be so in the future. Apparently the chief value of geologists in the oil business today is to explain why oil was found where it was after it was found and to make predictions about adjacent, not remote or new territory. Ask any oil producer.

THE CHAIRMAN. If there is no further discussion, I am going to give Dr. Lucke five minutes now in rebuttal.

DR. LUCKE. Gentlemen, there is nothing to rebut and I therefore will not take any more of your time. But in view of the novelty of the subject, and its scope, and the very great importance that there is in it measured by possible consequences in the form of changes in future practice, the suggestion is offered to you that you might think the situation over, discuss the matter with your friends and then when questions arise, as they surely will, send the questions to your Secretary and if your Secretary will communicate the questions to me, I will undertake to have them answered.

APPLICATION OF A BOOSTER PUMP TO A GRAVITY SYSTEM OF WATER SUPPLY.

BY GEORGE F. MERRILL.*

[*February 13, 1923.*]

In order to show conditions connected with the installation of the booster pump, and its effect on the whole system, a brief description of the works is desirable.

The water works at Greenfield were constructed by a fire district in 1872 and operated by it, until about a year ago, when they became the property of the town. Water is supplied to the whole town, with the exception of part of the farming district. The portion supplied includes a population of about 15 000 people. The manufacturing use is of about the average character, with no manufacturer requiring any considerable amount of water for process use. There is a fairly high consumption by railroads and hydraulic elevators. The average daily consumption is 100 gal. per capita. Services are about 15 per cent. metered, covering all except purely domestic use. The supply mains and pipes of the distribution system are of cast iron, with the exception of $\frac{1}{2}$ mi. of wood pipe.

The sources of supply are Glenn Brook, by gravity, with a water-shed of $5\frac{1}{2}$ sq. mi., in the town of Leyden; and Green River, emergency pumping, with a water-shed of about 52 sq. mi., part of which is in Vermont. On Glenn Brook two reservoirs are located, the upper being a storage reservoir with a capacity of 44 000 000 gal.; and the lower, a distributing reservoir with a capacity of 26 000 000 gal. In the wet years and also the normal years, with favorable distribution of rainfall during the summer months, the Glenn Brook water-shed yields sufficient run-off to supply the town. During dry seasons, when Glenn Brook water-shed fails, water is pumped from a well near Green River. This water flows through a natural deposit of sand and gravel to enter the well, and is therefore a filtered supply.

The Green River pumping station is operated by electric power, and contains a 3 000 000 gal. pump, built by the Platt Iron Works Company of Dayton, Ohio. It is 16 x 18 duplex horizontal pump, direct connected to a 200-horse power slip-ring type two-speed motor, through a single reduction of herringbone gears. The two-speed motor allows pump operating rates of 1 500 000 and 3 000 000 gal. per 24 hrs. Water at this station is pumped against an average static head of 245 ft., through a 16-in. force main about 2 600 ft. in length to the point where it connects with the gravity supply mains from the lower reservoir to the town. The dynamic head

* Superintendent Water Works, Greenfield, Mass.

varies from 250 to 285 ft. During the dry years it has been necessary to pump about 100 000 000 gal. per year. The Green River Works for additional supply were built in 1913 and 1914. Prior to 1914, emergency pumping was furnished by a stream plant from the Green River water-shed, taking water directly from the stream, which was discontinued when the additional supply works became available.

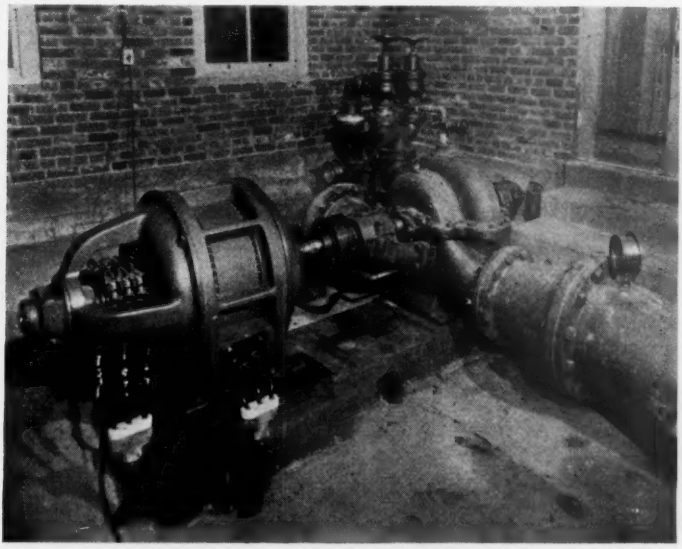

FIG. 1. MOTOR AND PUMP, SHOWING RELIEF VALVES, GREENFIELD, MASS.

The gravity supply mains from the lower reservoir to the town are parallel. 8-inch and 14-in. cast-iron pipes, with five 8-in. cross connections, allowing the flow to equalize itself in both pipes, which are about 20 000 ft. in length, from the lower reservoir to the northern part of the residential section of the town, where the pipes of the distribution system begin to assist the capacity of the main pipes, and about 26 000 ft. to Main Street, where they connect with the 24-in. main.

The upper reservoir on Glenn Brook is about 50 ft. higher than the lower reservoir, and is connected to the gravity supply mains at a point a short distance below the lower reservoir by a 30-in. main 2 170 ft. in length.

There is also an equalizing reservoir, called Rocky Mountain Reservoir, located on Rocky Mountain on the easterly side of the residential section, about one mile from the principal mercantile section, having capacity of 2 500 000 gal., and at an elevation of 200 ft. above the principal mercantile section. When filled, its water surface is 32½ ft. lower than the surface of the lower reservoir. This reservoir is connected with the distribution

system by a 24-in. main about 5 000 ft. in length, which extends through the business section and connects with the mains of intersecting streets.

During average conditions of supply, and all times when the consumption does not exceed 1 500 000 gal., for 24 hrs., water is supplied from the lower reservoir, and the supply mains will deliver this amount by gravity flow and keep the Rocky Mountain Reservoir full. As this reservoir is of great importance to furnish a ready volume of water for fire service at hydrant pressure, it is very essential that it be maintained practically full at all times. At times, water consumption is at considerably higher rate than the capacity of the supply mains. If this condition does not continue over a considerable number of days, the Rocky Mountain reservoir will furnish supply enough, as it has the night flow to fill it when water consumption for legitimate use is at a low rate.

In case the higher rate of consumption is continued for several days, its effect will be lowering of the water level in Rocky Mountain Reservoir, — unless a higher rate of flow in the supply mains can be furnished. Previous to the installation of the booster pump, the higher rate was obtained either by operating the Green River pumping station or by using the upper reservoir with its additional head and feeding through a throttled valve at the rate desired. In the winter season either method is expensive and wasteful, as in either case considerable quantities of water must be wasted in order to maintain circulation enough to prevent freezing in the exposed lines of pipe which pass through the gorge below the lower reservoir.

The booster pump is located at a point on the supply mains about 5 000 ft. towards the town from the lower reservoir, and about 1 000 ft. towards the town from the point where the force main from the Green River Pumping Station connects with the supply mains. The station is a brick building 18 x 22 ft. in which the pump is located. The pump is connected on a by-pass from the 14-in. main, and a 16-in. check valve is located in the main line between the branches, a larger check valve than the main-pipe size was used to eliminate as much as possible of the loss of head which this type of valve causes.

The pump is an 8-in. Worthington Centrifugal, with bronze impeller adapted to the hydraulic conditions, direct connected to 50 h. p. 550 volt-1 735 r.p.m. approximate full-load speed, from M, slip-ring-type, constant-speed motor—with drum controller. The control panel contains an ampere meter, one indicating watt-hour meter, a recording watt-hour meter, and starting switch with automatic oil circuit breaker with double-series, inverse-time-limit overload trip. The electrical equipment was furnished by the General Electric Company. On the discharge side of the pump are connected two 4-in. Crosby water-relief valves as a protection from surges of pressure.

The water pressure on the pump is 86 lb. When operating, the water pressure drops to 82 lb., on the suction side, and on the discharge side the pressure is 108, indicating a dynamic head of about sixty feet. The in-

creased pressure of 22 lb., on the discharge side is practically all consumed in friction loss in the supply mains due to the higher velocity. The discharge rate is 2 600 000 gal. per 24 hrs., increasing the capacity of the supply mains above the rate of gravity flow from the lower reservoir, by 73 per cent. The increased capacity was possible in our case because of low velocity obtaining under gravity flow from the lower reservoir, the calculated

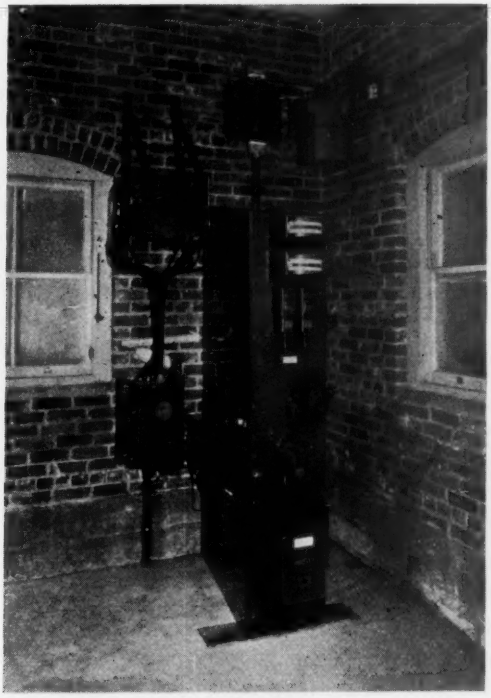

FIG. 2. CONTROL PANEL, BOOSTER PUMP, GREENFIELD, MASS.

Motor Control Panel, with Ampere Meter, Indicating Watt Hour Meter, Recording Watt Hour Meter and Starting Switch, with Oil Circuit Breaker, and Double Series Inverse Time Limit Overload Trip.

velocity being 1.67 ft., per sec. With the booster pump operating, the velocity increases to 2.78 ft. per sec.

Operating tests on the pump have shown the plant efficiency to be 75.2 per cent., which may be considered high for a plant of this size and type of pump.

The cost of installation was about $6 300 which included the building and all equipment and also covered the cost of about 3 300 ft. of three-phase, electric-power line.

The cost of pumping with electric power, at an average price of 2½c. per k.w. hr. will be about $8.20 per mil. gal., and the cost per mil. gal., raised one foot dynamic will be about thirteen cents.

The value to our system lies in the fact that an expenditure of about $200 000 for larger supply mains may be delayed until more favorable construction costs can be obtained.

In connection with this work, Allen Hazen, Consulting Engineer of New York, was consulted, and the work of installation was done by the department.

The cost of operation will be low, as present conditions indicate that an average run of a few hours a day will provide the necessary added capacity.

The successful application of a booster pump in other systems to increase main pipe capacities will depend wholly on the local conditions; and the greatest gains can be obtained in cases where the velocity of flow in the main pipes is low, thus permitting increased velocities and still keeping within the limit of economy in operating.

Present construction and operating costs make it imperative that water-works engineers and managers obtain as high efficiency as possible in every way. If there are cases where we can make our mains work more efficiently, substantial savings can be made; as they represent a considerable portion of the cost of every water system, and, as has been shown, it may sometimes pay to pump water down-hill.

Discussion.

President Sanders. I would like to ask, Mr. Merrill, if you have any means of measuring the water that is pumped—any Venturi meter on the discharge side of this pump?

Mr. Merrill. The discharge is metered by Venturi meter at a point about a mile from the station, and in considering the efficiency we have to make an allowance for what leakage occurs between the station and the meter. There may be some.

President Sanders. Do I understand you to say that you pump without an attendant at the pump.

Mr. Merrill. Well, we have not yet. It has only been operated a short period. It is a question of starting and stopping. Running for a stated period which can be determined beforehand. Possibly two hours today and three tomorrow is all that is required. That can be determined beforehand.

President Sanders. Do you always find that the check valve works? That is, when you start your booster pump does the operation of the pump close your check every time?

MR. MERRILL. We have found it did so far. I would say that those who are contemplating an installation of this kind had better look up the loss of head that you get from the check valve. We made it a size larger than the main-pipe size to avoid that as much as possible, but it has quite an advantage in the fact that when you shut your pump down it allows the flow to go along the main line, preventing a surge in pressure which might be quite destructive in a long line.

MR. E. P. HOWARD.* I do not know as I ought to take the time to say anything, as the hour is getting late. But I might just say that you probably noticed from Mr. Merrill's remarks the high efficiency of the pump, which figured out about 84 per cent., and which coincides very closely with what our President, Mr. Sanders, obtained with a similar installation in his plant. Now, that simply shows what can be done with a centrifugal pump of the right kind under the most favorable conditions when it is put in. A great deal of credit for this is due to the way it is installed. A large amount of credit is also due to how carefully the heads were figured out, so as to bring everything to practically a 100 per cent. point. The heads actually, I believe, in service, worked out within 5 ft. of what they were calculated in both of these plants.

Now I hope you won't take these two plants and the high efficiency that is obtained as something which would indicate that centrifugal pumps can be used in all places. In some places — in fact, places like this, where everything is favorable — they are the best thing in the world to use. There are other places, however, where they are the poorest thing in the world to use. Every job must be gone over, and every kind of a pump investigated to determine which is best for any particular case. In cases like this, as has been proved, it was the ideal thing.

* Of Worthington Pump and Machinery Corporation.

TOPICAL DISCUSSION.

WATER RATES.

[*February 13, 1923*]

MR. A. C. DICKERMAN* (*by letter February 8, 1923*). In response to the suggestion on the recent notification of the February 13th meeting, I would like to hear what some of the other members have to say as to the desirability and possibility of making rates that will insure the Water Company getting a satisfactory return for water sold to takers owning more than one house upon a lot or parcel, and who are supplied with water taken through a single meter located on that property.

It does not seem just to the Water Company that when a real estate owner has built several houses on a lot he should be able to buy water at wholesale from the Water Company and perhaps retail it to the tenants in the several houses, and it might also be considered a discriminatory practice.

It would seem wise to require a separate service and meter for each house, even when two or more houses are on the same parcel of land owned by a single party, in all cases where said services may be installed without unusual cost, and in other cases, permit a single service and meter but require a payment for each family or house supplied in addition to the actual price of the water passed through the meter.

I would be glad to hear what some of the other members have to say on this matter with particular reference to a privately-owned company.

I have been making some investigations of our accounts, and I find in my particular Company that it has been the practice in times past to connect up property, supplying it with water, so that later on, perhaps, when new houses were built on this parcel they would take the water from the original house and through the original meter. I think that this is wrong as it is not fair to the company.

There have been a number of such houses supplied, and I was startled when I found out how far it had gone. I have no doubt this condition is not an unusual one in other communities, because when towns are being developed of course the development is scattered. There is no rule requiring houses to be built next to each other on any particular street; consequently, there are a great many cases where some one wants water, and it is difficult, perhaps even prohibitive, as far as expense is concerned, to supply them from new mains. As a result the water companies have found temporary ways of supplying them with water, and I believe that these conditions lead to a very distinct loss of revenue.

Perhaps some of the members here have been able to work out some way of handling this situation satisfactorily so that proper terms will be made giving the Water Company a reasonable revenue and at the same

* Superintendent East Providence Water Co.

time not being too harsh on people who would otherwise have difficulty in getting water.

MR. H. J. GOODALE.* In Attleboro when the water system was first installed, and for a number of years after, each property-owner was allowed to connect as many houses to one service as he wished. This rule still applied after meters were introduced so that the owner of the property had the privilege of purchasing water at wholesale. After a period of time the Water Commissioners made a rule that each house must have a separate service but nothing was done to correct the existing conditions.

When the town became a city and new regulations were made it was decided that in all fairness, these conditions should be corrected so that a new rule was passed which was this: Where more than one building is served by one meter, water used in such buildings shall be charged for in the same manner and at the rates as though a separate meter was set in each building. Excess water shall be apportioned equally among the buildings so served.

Should more than one meter be set in any building, the established water rates shall be charged for each meter set, and in no case shall the water measured by one meter pass through another meter.

The term "building" shall include garage, barn or other out-buildings appurtenant to the main building.

MR. REEVES J. NEWSOM.† Our experience in Lynn has been very similar to that in Attleboro. In times past more than one house was occasionally served by a single service, through one meter in the front house, and our practice has been in recent years not to allow any installations of that kind, but on those installations that were already in operation a minimum charge was attached to each house and then the excess was billed. Ordinarily the bill went to one owner anyway, and he merely paid two minimum charges, or three, as the case might be, plus the excess at the base rate, so that the amount of his bill was exactly the same as though it were for three independent houses. The only advantage that he could derive in that case would be that he would pay for a single meter installation rather than for three, and that is the only argument we now have to meet where the physical conditions are such that this sort of thing could take place.

MR. HENRY V. MACKSEY.‡ Another phase of that question has not as yet been touched upon. We have a landlord who owns town house property built in blocks of three or four, and one of his ideas on economy is that he will serve his tenants only with the minimum amount of water for which he must pay, and he will leave them to pay the rest.

He notified us that we might collect from them, which we did not consider practicable, and we refused to do it. He then requested that we give him a separate meter for every tenement, which request we refused. Then, as he would not pay the rates demanded we shut the water off. The Board

* Town Manager, Middleborough, Mass.
† Commissioner of Water Supply, Lynn, Mass.
‡ Superintendent of Public Works, Framingham, Mass.

of Health intervened and demanded that the water be turned on. Then, we called upon the Board of Health — it was a health matter — to pay the water rates from the funds at their disposal before we turned the water on. That shut off the Board of Health for awhile. If it was a matter of health, why, the Health Department should take care of it; if it was a matter of selling water, we would not sell the water unless assured of payment. The landlord then came around with his tenant and the tenant demanded water, which we refused and we referred the matter to the Town Council, who said, "Why, you are supposed to supply water to all the citizens of Framingham whether they do or do not own property." We explained our difficulty in collecting bills. He said, "you may make any *reasonable* regulation you please, but you must supply the water." It appeared to us that the reasonable regulation was, that instead of one service supplying the block with one meter, there would have to be a separate service go into each tenement, each tenant having his own meter. We accepted tenants applications, and put in the meters. All went well until one tenant left. He came in and reported that he wanted no more water. We settled with him. Then he went to settle with his landlord, and he wanted to deduct what he had paid for his share of the service, his plumber's bill and his minimum water charge. The landlord, being of a trusting, unsuspicious nature, came around to us to find out how much money the tenant had spent. We would not tell him. We told him we were not doing business with him at all; we didn't know him in the matter. He sent his counsel in, and the counsel said, "Why, the statute says that the landlord, the owner of the property, is responsible for all the water served to his tenants." We said, "Why, we know it does, because our counsel told us so; but our counsel also told us that we have to supply the tenant if he demands it." We did not go to counsel the third time, because we did not think it was necessary to have him tell us that if we make a deal with John Smith that we cannot tell Tom Jones he will have to pay the bill later on. We said, "You didn't have any part in the contract; the contract you had with us to supply water to the premises was ended when we began to do business with the tenant. You said you would not pay any part of it." Well, the counsel for the landlord, after talking for a half hour, went away. He did not get the facts or the figures. But we have a new town counsel now, and we are going to ask him if a regulation to the effect that we will sell water to the owners of real estate only and not to the tenants is a reasonable regulation.

PRESIDENT SANDERS. I think your regulation would be a very reasonable one, Mr. Macksey. That is the way we have the good fortune to do. We collect from the owner only; we don't know who the tenant is. It is a good deal easier to find the owner than it is the tenant.

MR. MACKSEY. I will tell you about another thing along the same line. We are just about to establish a sewer-rental system and one of our big business men is on the committee to arrange therefor. He has been a

Water Commissioner for a number of years. When he was placed on the committee for establishing sewer rentals, he wanted to get out of it easy, so he said, "We will make the rental a surcharge on water." So now the sewer rental is a surcharge of 35 per cent. on water. He said further, "You can add it to the water bills." But the Act under which the sewer rental was established says it shall be collected the same as taxes. Now, the taxes are collected by a tax collector, upon a warrant which is served by an officer, or whoever it may be that serves them, and he collects ordinarily. He serves a notice and if payment is not made by a certain date interest goes on at 6 per cent. It costs a quarter for the notice, or something like that. He then serves another notice, which costs another quarter and then sends a man after you and charges $2.50. After a while perhaps he threatens you with jail. He usually advertises the property for sale and gets or sells the tax title. That is different from our method of collecting for water. If a man gets a water bill and it happens to be $10 for water and $3.50 for sewer, and says, "Here is your $10 for the water," we must serve him water. But our counsel seems to think that it is proper to render the both items as one bill, and if any part is unpaid to shut off the water.

Mr. George W. Batchelder.* We have very few places that are supplied by one meter.

I just want to say one thing touching on what Mr. Macksey has said. We do not have anything to do with selecting the Town Counsel — or City Solicitor, as we call him in Worcester — but we try to have a lot to do in training him in water-works law.

Mr. Stephen H. Taylor.† In New Bedford we make the owner of the building responsible for the water rates. If he wants to sub-divide his bill among his tenants he buys his own private meters and puts them in the branches that go to his various tenants. We bill according to the main meter where the water enters the property. We have been able to get away with that very comfortably so far.

On the matter of connecting, we do sometimes connect the services through to a house in the rear, and I think perhaps the idea of getting the minimum charge for that connection is good, although we have not done it in New Bedford. It occurs to me, however, would that be a proper charge if a man built a garage, for instance, in the rear of his house and wanted to run the water pipe back there for convenience, to a part of the same property? We do not have very many cases where we connect one to another except where a house in the rear faces a street on which there is no water. Then naturally it is better to do that than it is to put in a new main for him.

There is another side to that question. In New Bedford, for instance, we get a tapping fee of $2 for service that costs from $25 to $35 to put in. Now, if we can get two houses on that one service we are about $22 to $32 to the good on the original outlay. If the owner pays the whole bill, that would be another matter. In our particular case the city bears the larger part of the cost of the service.

* Water Commissioner, Worcester, Mass.
† Superintendent Water Works, New Bedford, Mass.

MR. DICKERMAN. I am reminded of a couple of things that have come to my attention in our company. In one case, some ten years ago, a thing of this sort was done. A man who had a house asked for water, and he immediately built a second house back of him on a street in which there is no water. Then he built two more houses upon this second street. The necessary papers were drawn up, giving the Water Company an easement to cross this second lot into the second street, to reach the last house built. The second house was later sold and then sold again, and in the last sale nothing was said in the deed referring to this original easement. Then the last owner got the idea that he was damaged, and sued the man who sold the property to him, for $2,000 and tried to collect. Of course the parties came to me and wanted some help. It meant in our case running about 500 ft. of pipe at our expense to overcome the cause of the suit, and I believe we will actually do it, because we want to eliminate these unsatisfactory and illogical arrangements of pipes. But this puts a burden on the Water Company, as there will not be enough customers, probably, to even pay the interest on the money involved.

There is a second case somewhat like this although the company will not be put to much expense by it. A service pipe was run across a lot to reach a house in the rear, the property was divided and sold to two different people, but nothing was said in the deed about the water pipes. This developed into a neighborly row and has been taken to the courts.

MR. HENRY T. GIDLEY. We have a situation in Fairhaven that is somewhat similar to the last speaker's. A man built a store on the main-pipe line with a tenement above. He lived above his store. After a little while he built a cottage back of the store. There was no water pipe on the other street, and he wanted to connect to the same meter the pipe that ran through the cellar of the store into the cottage in the rear. We allowed him to do that, and all went well for a while, until finally he sold his cottage to one party, and the store to another. Then we collected a minimum amount from the party in the rear. But the man who bought the store had a lot of surface water run into the cellar, and he had to pay for an enormous quantity of water which he used in a water motor to pump out his cellar every time it rained, so that his bill ran up excessively large, and he refused to pay it. The people in back had already paid their bill, and when we shut him off for a part of the day to see if we could not force him to pay, it was hardly fair on the people in back. He scraped up $5 and said he would pay the rest. There was no way we could collect it. But finally the original owner of the store foreclosed the mortgage on the property, and when the final papers were passed he made the man deposit enough money to cover the water bill, so that we got out of it that way. The first thing we did was to lay a pipe down that street and connect up with the other houses. There are very few places that we have had that way, and most of them have turned out disastrously. Where a man owns two houses, and one is back of the other, we let them run through one meter, but we collect the minimum charge for both houses.

* Superintendent Water Works, Fairhaven, Mass.

REPORT OF THE JOINT COMMITTEE ON STANDARD SPECIFICATIONS FOR WATER METERS.

To the American and New England Water Works Associations:

Your Committees on Standard Specifications for Water Meters, acting as a Joint Committee, now submit a final report accompanied by a draft of Standard Specifications for Cold Water Meters of the current, compound and fire-service types. There has not appeared to be any reason for modifying the specifications for meters of the disc type which were adopted by the Associations in 1921.

The specifications for disc meters were printed with the Committee's report which was submitted to the American Water Works Association on June 9, 1921, and to the New England Water Works Association on September 14, 1921, and may be found in the American Association's Journal for that year, page 273, and the New England Association's Journal, page 187. That report was submitted as a final report upon the assumption that a standard specification for disc meters was all that was really needed, since few, if any, meters of other types are bought on the basis of competitive bids. Both Associations, however, indicated their desire that the Committee continue its work and prepare specifications for the other principal types of meters, as well as giving consideration to the experience with the specifications for disc meters with a view to revising them, should any change prove desirable.

The experience of two years with the standard specifications for disc meters has not indicated the desirability of any change.

Your Committee decided to prepare similar specifications for current, compound and fire-service types of cold-water meters. It did not seem necessary or desirable to attempt standard specifications for hot-water meters.

The specifications for disc meters have served as a general basis for those of other types. Through the coöperation of the Standardization Committee of Meter Manufacturers, Mr. R. K.

Blanchard, chairman, a preliminary draft of standard specifications for current and compound meters was prepared. This was circulated to the membership of the Joint Committee and later was discussed in detail at a meeting of the Committee, when certain modifications were decided upon, and it was also agreed to prepare specifications for fire-service meters. The modifications proposed were worked out and incorporated in the draft of specifications on behalf of the Joint Committee by Mr. Edward Nuebling of the Department of Water Supply, New York City, to whom the Committee is greatly indebted for this and for other assistance in its work. The revised draft was further considered by the Committee and by representatives of the meter manufacturers before its adoption in the form now submitted to the Associations.

In connection with the specifications your Committee decided to present certain prefatory notes, including information submitted as addenda to the specifications for disc meters, and other explanatory matter, which it was felt ought to be available in connection with the specifications, although not properly forming a part of them.

It is assumed that after the standard specifications have been adopted by the Associations they will be reprinted, together with the specifications for disc meters, in a single pamphlet for general use.

One point which the Committee does not consider practicable to standardize through the specifications at the present time, but which it is hoped the manufacturers may find it possible to standardize in the not distant future, is the arrangement of dials on meter registers. It is very unfortunate that the sequence of dials should vary with certain makes of meters, but it has not seemed wise to your Committee to attempt to fix a standard in this respect for immediate adoption.

Respectfully submitted,
For the Joint Committee.

CHARLES W. SHERMAN, *Chairman.*

William W. Brush, *Chairman.*
Charles W. Sherman,
A. W. F. Brown,
R. J. Thomas,
Henry V. Macksey,
James A. McMurry,
John H. Walsh,
N. E. W. W. Ass'n Committee.

Caleb M. Saville, *Chairman.*
Dow R. Gwinn,
R. J. Thomas,
Seth M. Van Loan.
Am. W. W. Ass'n Committee.

FEBRUARY 24, 1923.

GENERAL INFORMATION.

(These notes are not a part of the specifications. They are inserted for the purpose of providing proper definitions and general information which is frequently necessary in calling for bids, testing meters, or otherwise passing upon their suitability.)

Types of Meters.

Service meters in use for measuring water delivered to domestic and commercial consumers are divided into four general classes, as follows: displacement, current, compound and fire service.

Displacement Meters. There are a number of different types of displacement meters on the market which are known by the motion of the piston, as, reciprocating, rotary, oscillating and nutating disc meters. These meters are positive in action and displace or carry over a fixed quantity for each stroke or revolution of the piston or disc.

Displacement meters are manufactured in sizes from $\frac{5}{8}$ in. to 6 in. They are suggested for universal use on supply lines to dwellings and for use in other locations where accuracy of measurement is a primary consideration.

Current Meters. There are several different types of current meters on the market which differ from each other mainly in the shape of the water wheel or propeller. These meters are not positive in action, but record the flow by the number of revolutions of their water wheel or propeller, which is set in motion by the force of the flowing water coming in contact with the wheel or propeller blades.

Current meters are manufactured in sizes from $1\frac{1}{2}$ in. to 20 in.* These are cheaper in first cost and maintenance and offer less obstruction to the flow of water through them and therefore give a greater discharge with the same loss of head than displacement meters. They are not sensitive to small flows, and not as accurate and reliable as meters of the displacement class on the larger flows.

Meters of the current type are appropriate where a free discharge and heavy service is demanded, as for example: railroad standpipes, elevators, water carts and water motors.

Compound Meters. Compound meters consist of the combination of a main-line meter of the current or displacement type for measuring large flows and a small by-pass meter of the displacement type for

* Sizes larger than 12 in. are so rare that the Committee has not attempted to give the detailed figures for meters above that size.

measuring small flows, together with an automatic valve mechanism for diverting the small flows through the by-pass meter.

The automatic valve, which is of the differential type, remains closed until the flow is large enough to create a fixed difference in pressure between the inlet and outlet side of the valve. The by-pass meter measures the small flows that otherwise would not be measured or would be measured in part only by the main-line meter. Compound meters are manufactured in sizes from 1½ in. to 12 in. They are suggested for use in cases where flows through the meter cannot be confined to rates within the accuracy limits of a single meter.

Fire-Service Meters. Fire-service meters are compound meters consisting of a main-line meter of the proportional type for measuring large flows and a small by-pass meter of the displacement type for measuring small flows together with an automatic valve mechanism for diverting the small flows through the by-pass meter. The combination is designed to afford a clear passage through the meter when the valve is raised from its seat.

Fire-service meters are manufactured in sizes from 3 in. to 12 in. They are the type required by the Fire Underwriters on sprinkler or fire hydrant connections if minimum fire insurance rates are to be secured. The measurement of flow recorded on the main-line meter is liable to be inaccurate unless careful attention is given to keeping all parts of the meter in good working condition. When the flow through the meter is such as to bring the main-line meter into use, only a relatively small portion of the total flow actually passes through the main-line meter. This increases the liability of serious error in the registration of the water passing through the meter.

Maximum and Minimum Lengths of Meters.

A standard over-all length has been fixed for each size of disc meter. Due to the large variation in the over-all length of each size of current and compound meters that exists among the various makes of meters, it has been found impracticable to fix a standard over-all length for these types. A filler piece can be inserted to increase the length of the shorter meters. Manufacturers are prepared to supply these filler pieces when required.

The following minimum and maximum over-all length, in inches, of the various sizes and types of meters is given to aid those who may desire to provide space for the maximum length of any meter:

Size, Inches.	Disc Standard Length.	Current Minimum Length.	Current Maximum Length.	Compound Minimum Length.	Compound Maximum Length.
$\frac{5}{8}$	$7\frac{1}{2}$	—	—	—	—
$\frac{3}{4}$	9	—	—	—	—
1	$10\frac{3}{4}$	—	—	—	—
$1\frac{1}{2}$	$12\frac{5}{8}$	13	$15\frac{1}{4}$	$18\frac{5}{16}$	$18\frac{5}{16}$
2	$15\frac{1}{4}$	$15\frac{1}{4}$	19	$15\frac{1}{4}$	$28\frac{7}{8}$
3	24	20	24	24	$37\frac{1}{8}$
4	29	22	$29\frac{1}{4}$	29	$39\frac{1}{4}$
6	$36\frac{1}{2}$	24	$36\frac{3}{4}$	36	$50\frac{3}{4}$
8	—	$26\frac{3}{4}$	$48\frac{3}{4}$	42	$61\frac{3}{4}$
10	—	30	60	$63\frac{1}{2}$	$72\frac{3}{4}$
12	—	36	70	$64\frac{1}{2}$	77

Tests of Meters Recommended.

The tests to be made on the meter are divided into two classes:

1. Capacity test.
2. Registration test.

Capacity tests are those which test the design of the meter rather than the workmanship thereof. When a meter of a given make has once been tested for capacity it should not be necessary to again test this type of meter unless a change has been made in its design.

The registration tests should be made on each meter, as the results are affected by workmanship and assembly of individual meters. There is no certainty that, because one meter of a given make comes within certain limits of accuracy, another meter of the same make turned out by the factory on the same day will necessarily give similar results. The register furnished with each meter should be used by both the manufacturer and purchaser in making registration tests.

The registration tests recommended are as follows:

All meters should be tested for accuracy of registration within and as near as practicable to the low and high rates given under "Normal Test Flow Limits." Occasionally additional tests should be made at one or more intermediate points.

A test at the "Minimum Test Flow" should be made on as many as possible and not less than 5 per cent. of the meters. If the results obtained from testing 5 per cent. of the meters show that any meter does not comply with the low-flow requirement, additional

meters should be tested to the extent deemed necessary to make certain that the other meters do comply therewith.

The accuracy of compound and fire-service meters within the "change over" range should be determined by making a sufficient number of tests at different rates of flow between the high and low rates given under "Normal Test Flow Limits" to enable the construction of a representative accuracy curve. The rates of flow at the beginning and end of the "change over" and the maximum error in registration can readily be determined from this curve.

A test for accuracy at the "change over" should not be necessary on all meters since this is a test of design rather than workmanship.

Attempt should not be made to test large-size meters if the higher rates of flow necessary to make a proper test cannot be obtained with the apparatus available.

The pressure test should be made on each size of meter furnished of a particular type. This pressure is to be 150 lb. per sq. in. and the pressure may be furnished through the use if a hand pump or such other method as may be available. Before the meter has been tested by static pressure and also after it has been so tested, it should be tested for accuracy to see whether the meter has been so distorted as to affect registration. It is considered unnecessary to make a pressure test of each size of meter of a given type more than once if satisfactory results are obtained.

If it be possible to give a working-pressure test under 150 lb. per sq. in., then such a test should be applied rather than a static-pressure test.

Where the purchaser does not have the necessary equipment to test the meters, there should be furnished by the manufacturer a certificate that each meter has been tested for accuracy of registration and complies with the standard specifications in this respect, and that the size and type of meter furnished has complied with the capacity requirements. When compound or fire-service meters are purchased, the certificate furnished by the manufacturer should include a statement to the effect that the size and type of meter furnished has complied with the standard specifications in respect to registration of flows within the "change over" from the by-pass meter to the main-line meter.

Equipment Necessary to Test Meters for Compliance with Registration and Capacity Requirements as Set Forth in the Standard Specifications for Water Meters.

The standard specifications require that meters shall accurately record the flow within certain limits and shall pass a given quantity of water with a maximum loss of pressure. Suitable equipment to make accurate tests must be available before the purchaser should make complaint of meters not complying with the specifications.

The minimum test equipment required for registration and capacity is as follows:

1. A quick-acting valve on the supply pipe through the use of which the flow can be started and stopped without appreciable loss of time.

2. A valve on the outlet side of the meter which can be used to establish the rate of flow desired.

3. Pressure gages connected on both the inlet and outlet of the meter to show whether any material change in pressure occurs during the period of test which would affect the rate of flow. The outlet pipe is to have sufficient head on it so that the meter will always have pressure on its outlet end and preferably not less than 5 lb. per sq. in.

4. A measuring device which may be either of the volumetric or weighing type. Whichever is used, the accuracy of determination of the volume or weight of water discharged into the measuring device must be such as to bring the limit of error within one-tenth of 1 per cent. The volume of water passed must be sufficient to cause at least one revolution of the pointer on the initial dial except for test at "minimum test flow" rate. For the latter test, the amount passed shall not be less than one cubic foot.

It is desirable to have available for testing meters a test table and appurtenances which are manufactured by several concerns. Such an outfit would include the equipment enumerated in the preceding four paragraphs.

For the capacity tests, it is necessary to add to the above equipment, two piezometer rings which must be of exactly the same diameter. The piezometer rings must be free from any burrs where the holes are drilled through the wall of the ring and not less than four holes shall be provided, drilled in pairs and on diameters at

right angles to one another. The inlet piezometer ring shall be set close to the meter and shall be at a distance of not less than eight diameters from the nearest upstream stop-cock or fitting in the supply pipe. The outlet piezometer ring shall be placed at a distance of not less than eight nor more than ten diameters from the outlet of the meter. The diameter of the piezometer rings and inlet and outlet pipes shall be the same as the size of the meter to be tested. The piezometer rings are to be connected by either rubber or metal tubing to a mercury U-tube. To this U-tube is to be attached an accurate adjustable scale for measuring the differences between the inlet and outlet pressures. Provision is to be made for the complete removal of air from the tubing connected with the U-tube, and the U-tube and the tubing connected therewith are to be so placed that the air will rise to the outlets. Where relatively high flows are to be recorded, it is necessary to read both sides of the mercury column to compensate, as far as practicable, for irregularities in the diameter of the glass U-tube, and such readings are to be made as nearly simultaneously as possible to avoid errors due to fluctuations.

Information to be Furnished to Meter Manufacturers When Requested to Submit Bids on Meters.

1. Meters shall conform to the Standard Specifications for Cold Water Meters, ... Type, adopted by the American and New England Water Works Associations.

2. The manufacturer shall state in his bid the type of meter he proposes to furnish, as listed in his catalogue. The actual capacity of each size of meter called for is to be given graphically from 0 lb. up to 25 lb. loss of pressure. If this capacity be stated in the manufacturer's catalogue reference may be made thereto.

3. No bid will be considered on meters of a design which has not been listed for at least one year in the catalogue regularly issued by the manufacturer.

4. The method of testing meters shall conform to that recommended by the Committee on Standard Specifications for Water Meters.

5. (*a*)* The meters are to be accepted on a certificate furnished by the manufacturers that the meters have met the requirements of the Standard Specifications for Water Meters, as adopted by the American and New England Water Works Associations.

(*b*)* The meters will be tested by the purchaser to determine whether they do or do not comply with the Standard Specifications for Water Meters adopted by the American and New England Water Works Associations.

6. Registers shall be {round / straight} reading, and shall record in {cubic feet / gallons}.

Care of Meters.

In all types of displacement and current meters the motions of the piston are transmitted by a system of gearing to the register where the flow is recorded in convenient units of measure, such as cubic feet or gallons. The gearing serves to translate the motions of the piston into the units of measure indicated by the register.

The register is at all times a measure of the number of revolutions of the piston. It records a true measure of flow only when the meter has been properly calibrated by gear adjustment, and, after proper calibration, will continue to register correctly only so long as the piston continues to make the proper number of revolutions for each unit of quantity passed through the meter. If, after calibration, any condition should develop whereby the piston is compelled to make less than the proper number of revolutions per unit of quantity passed through it, the meter will under-register. If the piston is compelled to make more than the proper number of revolutions, the meter will over-register. The proper number of revolutions is the number made at the time the meter is calibrated. The actual number is not important and is ordinarily not determined. There are, under ordinary working conditions, a number of factors that may cause under- or over-registration after comparatively short periods of time. The more important of these factors, which should be guarded against to secure proper registration, are described below:

Excessive Wear. Excessive wear of the moving parts of the meter may be caused by over-speeding, or, in general, by the selection

*Sentence (*a*) is to be used where the purchaser does not have suitable equipment to test the meters. If he has such equipment then sentence (*b*) is to be used.

of meters too small for the work required. The effect of excessive wear of the piston or piston chamber is to cause slippage and under-registration. Excessive wear of the intermediate gear train may cause binding of the gears, breakage of gear teeth or gear slippage. In any case, if the meter is not stopped entirely, under-registration will result. To avoid excessive wear, meters should not be run at destructive speeds.

The rates of flow corresponding to 25-lb. pressure loss, given in the standard specifications for cold-water meters, represent the maximum rates at which water should be passed through meters for short periods of time. They represent peak loads which should come upon meters only at long intervals. These rates would be destructive under continuous service. For continuous 24-hour service meters of the disc or displacement type should not be operated under flows greater than one-fifth the capacity of the meter. Meters of the current type can be operated at higher rates than displacement meters, but for continuous 24-hour service the rate should not exceed one-third the capacity of the meter. If a compound meter is to be used for continuous service at a more or less uniform rate of flow, care should be taken to select a size of meter in which the " change over " point is below the flow which is usually to be measured. Compound meters will not give reliable measurement within the " change over " range; that is to say, within the range covering the change over from by-pass meter to main-line meter.

Temperature. High temperature causes the vulcanized rubber pistons of cold-water meters to expand, tending to create unusual friction or to bind the piston in its chamber. The effect is to cause slippage and under-registration or failure of the meters. Low temperature has no noticeable effect on the working parts of a meter. Freezing will of course stop the meter and possibly damage it.

Cold-water meters are not affected by temperatures up to about 80° Fahrenheit. In warm climates where the temperature of the water is liable to go above 80° Fahrenheit, meters with clearances slightly larger than ordinary should be used. Manufacturers are prepared to furnish such meters upon request.

To avoid troubles due to temperature, meters should be set in locations where they will be protected from heat and frost. In locations where hot water from the heating system may be forced back through the meter or where it may be drawn back when the mains are emptied, a check and relief valve should be installed on the outlet side of the meter.

Corrosion. The metals used in water-meter construction are all affected, more or less, by the corrosive action of the water passed through them. The action is very slow under most potable waters. Its effect is to weaken parts of the meter, particularly the teeth of the intermediate gears. It may also bind meters lying idle for long periods of time. Tuberculation of the outer case in meters of the current type may change the normal direction of flow through the meter and cause over-registration. Vulcanized rubber is but slightly affected by the corrosive action of water, and where the supply is highly corrosive vulcanized rubber intermediate gears are recommended. To avoid possible troubles due to corrosion, particularly when meters are purchased in quantity, the meter manufacturer should be furnished with the chemical and physical analysis of the water supply. Given this information, the manufacturer can use a composition of metal which in his judgment is most suitable for the particular water in question.

Suspended Matter Carried by Water. Foreign matter carried by water in suspension has different effects on different types of meters. In meters of the disc and other displacement types fine particles of suspended matter settling in the meter have a tendency to fill the voids between the piston and piston chamber and cause over-registration. Such over-registration is, however, limited and cannot generally exceed 2 per cent.

In meters of the current type the speed of the piston wheel is proportional to the velocity of flow. Any conditions tending to change the velocity of flow, after the meter has been calibrated, will cause inaccurate registration. Accumulations of deposit always tend to cause over-registration and such over-registration is not limited, as in displacement meters.

All meters, except fire-service meters, are provided with strainers to hold back the larger particles of matter which may be carried in suspension by the water, but the meter strainer will soon become clogged if the water is not kept reasonably free of suspended matter. Sand is especially destructive to all types of meters, and care should be exercised to prevent sand from reaching the supply mains.

The finer particles of suspended matter cannot be prevented from reaching the meter and troubles from this source can be avoided only by cleaning the meter periodically, the interval between cleanings depending upon the quality of the water.

Periodical Tests Necessary to Insure Proper Registration. Water meters, properly selected as to size and type, will give satisfactory service over a long period of years without attention only when operated under ideal conditions. Under ordinary conditions meters must be given a certain amount of care to secure proper registration. In most cases it is impossible to ascertain without actual test whether or not a meter which has been in service is registering within the required degree of accuracy. Consequently, in order to insure reliable meter measurement it is essential that all meters be subjected to periodical tests. The interval between tests and the method of conducting them must be governed largely by local conditions. Under average conditions the following intervals between tests should not be exceeded:

Size of Meter.	Interval Between Test Years.
$\frac{5}{8}$ in., $\frac{3}{4}$ in., and 1 in.	5
$1\frac{1}{2}$ in. and 2 in.	4
3 in.	3
4 in.	2
6 in. and larger	1

Meters of the current and compound type used for measuring unfiltered surface waters should be cleaned about once a year to keep them in good working condition. When filtered or exceptionally clean water is used, the interval between cleanings may be longer.

Best results will be obtained from current meters if they are calibrated in place, since the accuracy of these meters is affected by changes in distribution of velocities through the meter. A meter of this type calibrated in a testing machine under conditions where there is a bend near the inlet side of the meter may register incorrectly from the start, if installed under conditions where there is a straight run of pipe in the inlet side. Any other condition tending to change the distribution of velocities as existent at the time of calibration will have the same effect. If calibrated on premises this source of error will be avoided.

For 3-in. and larger meters the installation of a test tee in the outlet piping makes testing easier and reduces its cost.

STANDARD SPECIFICATIONS FOR COLD WATER METERS.

Adopted by New England Water Works Asssociation, March 13, 1923.
Adopted by American Water Warks Association, May 24, 1923.

CURRENT TYPE.

Cases. The outer cases shall be made of bronze composition or of cast iron protected by a non-corrosive treatment. All meters shall have cast on them in raised characters the size and the model, and the direction of the flow through the meter shall be properly indicated. Meters shall be designed for easy removal of all interior parts, without disturbing the connections to the pipe line.

External Bolts. All external bolts shall be made of bronze or of galvanized iron or steel. Nuts shall be designed for easy removal after having been long in service.

Registers. Registers may be either "round" or "straight" reading, indicating in cubic feet or gallons.

All parts of the registers shall be made of non-ferrous material. The maximum indication of the initial dial and the minimum capacity of the register, when indicating cubic feet, shall be as follows:

Size, Inches.	Maximum Indication of Initial Dial. Cubic Feet.	Minimum Capacity of Register. Cubic Feet.
1½	10	10 000 000
2	10	10 000 000
3	10	10 000 000
4	100	10 000 000
6	100	100 000 000
8	1 000	100 000 000
10	1 000	100 000 000
12	1 000	1 000 000 000

All dials, including the initial dial, shall be sub-divided into ten equal parts. All hands or pointers shall taper to a sharp point. They shall be accurately set and securely held in place.

Register Boxes. Register boxes and lids shall be made of bronze composition or same material as the top case, with the name of the manufacturer cast on the lid in raised letters. The serial number of the meter shall be plainly stamped on the lid. If required, the serial number shall also be stamped on the case. The lid shall be recessed and shall lap over the box. The glass shall be inserted from the inside and securely held in place without the use of putty or pins. All register compartments shall be provided with a water-escape hole

$\frac{1}{8}$ in. in diameter, so placed that the change gear or registering mechanism cannot be tampered with.

Connections for 1 1/2 and 2-inch Sizes. Spuds shall be either flanged or tapped, as called for. Flanges may be either of the round or oval type. If of the round type, they shall conform to the American standard of Jan. 1, 1914. If of the oval type, the drilling shall be on the horizontal axis, and in accordance with the American standard bolt circle. If the spuds are to be tapped they shall be tapped for $1\frac{1}{2}$ and 2 in. respectively, with female thread of standard pipe size, and so tapped that Briggs standard pipe thread plug gages may be screwed in by hand up to the notch on the plug.

Couplings shall be made of bronze composition. Nuts shall be tapped 2 and $2\frac{1}{2}$ in. respectively, straight thread, standard pipe size and so tapped that Briggs standard pipe thread plug gages may be backed into the nuts by hand, i. e., the size of the thread in the nut is the maximum size of the Briggs plug, but no larger. Tailpieces shall be threaded $1\frac{1}{2}$ and 2 in. respectively, male thread, standard pipe size, and so threaded that Briggs standard pipe thread ring gages may be screwed on by hand flush with the face of the gage. 2 by $1\frac{1}{2}$-in. and $2\frac{1}{2}$ by 2-in. standard pipe size malleable iron bushings are to be furnished with $1\frac{1}{2}$-in. and 2-in. couplings respectively. Care shall be taken to see that nuts as above described can be screwed on to the bushings by hand and that the face of the bushings will be sufficiently true and square to provide a proper packing surface.

Over-all lengths of tailpieces shall be:

Size.	Length.
$1\frac{1}{2}$ in.	$2\frac{7}{8}$ in.
2 in.	3 in.

Connections for 3, 4, 6, 8, 10 and 12-in. Sizes. Spuds shall be flanged, faced and drilled. If called for, either companion flanges or bell and spigot connections shall be furnished. Companion flanges shall be of cast-iron, faced, drilled and tapped. All flange dimensions, drilling and tapping shall conform to American Standard of Jan. 1, 1914. Bell and spigot connections shall be made of cast iron and shall conform to the cast-iron water pipe specifications, class "B," adopted May 12, 1908, by the American Water Works Association, as far as these specifications will apply thereto. For the 3-in. size the dimensions shall be as follows:

(Letters refer to sketch in Table No. 1 of the A. W. W. A. pipe specifications.)

Actual outside diameter	3.96 in.
Diameter of socket	4.76 in.
Depth of socket	3.50 in.
A	1.25 in.
B	1.30 in.
C	.65 in.

The length of the bell connections from the face of the flanges to the seat of the bell shall be 6 in. for all sizes. The length of the spigot connections from the face of the flange to the end of the spigot shall be 18 in. for all sizes.

Seal Wire Holes. All meters shall have register box screws, inlet and outlet coupling nuts and one or more body bolts drilled for seal wire holes. All seal wire holes shall not be less than $^3/_{32}$ in. in diameter.

Measuring Cages. Measuring cages for all meters shall be made of bronze composition and shall be self-contained and easily detached from the main body casing.

Measuring Wheels. The measuring wheel for all meters shall be made of vulcanized rubber. The measuring wheel shall be mounted, or shall rotate, on phosphor-bronze or other suitable metal spindle and shall be supported by jewel, ball, or other suitable bearings. Measuring wheels mounted on spindles shall revolve in hard rubber bushed bearings. The measuring wheel, together with its spindle, shall be as nearly as possible of the same specific gravity as water.

Intermediate Gear Trains. The intermediate gear trains shall be of such construction as to be easily removed and shall be made throughout of non-ferrous material. Gear spindles may run in bearings bushed with hard rubber, provided the bushings are so constructed that they cannot drop out.

Strainers. All meters shall be provided with strainers made of or coated with non-ferrous materials. The strainers shall have an effective straining area at least double that of the inlet and shall be accessible for cleaning.

Registration. The registration on the meter dial shall indicate the quantity recorded to be not less than 97 per cent. nor more than 103 per cent. of the water actually passed through the meter while

it is being tested at rates of flow within the limits specified herein under "normal test flow limits." There shall be not less than 90 per cent. of the actual flow recorded when a test is made at the rate of flow set forth under "minimum test flow."

Size. Inches.	Normal Test Flow Limits. (Gal. per Min.)	Minimum Test Flow. (Gal. per Min.)
1½	12 to 100	5
2	16 to 175	7
3	24 to 400	10
4	40 to 700	15
6	80 to 1 600	30
8	144 to 2 800	50
10	224 to 4 375	75
12	320 to 6 400	100

Capacity. New meters shall show a loss of head not exceeding 25 lb. per sq. in., when the rate of flow is that given in the following table:

Size, Inches.	Gallons per Minute.
1½	100
2	175
3	400
4	700
6	1 600
8	2 800
10	4 375
12	6 400

Pressure Test. Current meters shall be guaranteed to operate under a working pressure of 150 lb. per sq. in. without leakage or damage to any part.

Workmanship and Material. Current meters shall be guaranteed against defects in materials and workmanship for a period of one year from date of shipment. Parts to replace those in which a defect may develop within such period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Rejected Meters. The manufacturer shall at his own expense, replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

Compound Type.

Definition. Compound meters are defined as those meters which consist of the combination of a main-line meter of the current or displacement type for measuring large flows and a small by-pass meter of the displacement type for measuring small flows, together with an automatic-valve mechanism for diverting the small flows through the by-pass meter.

Cases. All outer cases shall be made either of bronze composition or of cast-iron protected by a non-corrosive treatment. All meters shall have cast on them in raised characters the size and the model, and the direction of the flow through the meter shall be properly indicated. Compound meters composed of a combination of independent units in separate housings shall have this information cast on each unit. Meters shall be designed for easy removal of all interior parts without disturbing the connections to the pipe line.

External Bolts. All external bolts shall be made of bronze or of galvanized iron or steel. Nuts shall be designed for easy removal after having been long in service.

Registers. Registers may be either "round" or "straight" reading, indicating in cubic feet or gallons.

All parts of the registers shall be made of non-ferrous material. The maximum indication of the initial dial and the minimum capacity of the register, when indicating cubic feet, shall be as follows:

Size, Inches.	Maximum Indication of Initial Dial. Cubic Feet.	Minimum Capacity of Register. Cubic Feet.
	Main-Line Meters.	
1½	10	10 000 000
2	10	10 000 000
3	10	10 000 000
4	100	10 000 000
6	100	100 000 000
8	1 000	100 000 000
10	1 000	100 000 000
12	1 000	1 000 000 000
	By-Pass Meters.	
⅝	1	100 000
¾	10	1 000 000
1	10	1 000 000
1½	10	1 000 000
2	10	10 000 000
3	10	10 000 000

All dials, including the initial dial, shall be subdivided into ten equal parts. All hands or pointers shall taper to a sharp point. They shall be accurately set and securely held in place.

Register Boxes. Register boxes and lids shall be made of bronze composition or same material as top case, with the name of the manufacturer cast on the lid in raised letters. The same serial number shall be plainly stamped on the lid of both the by-pass and main-line meters. If required, the serial number shall also be stamped on the cases. The lid shall be recessed and shall lap over the box. The glass shall be inserted from the inside and securely held in place without the use of putty or pins. All register compartments shall be provided with a water-escape hole $\frac{1}{8}$ in. in diameter, so placed that the change gear or registering mechanism cannot be tampered with.

Connections for 1 1/2 and 2-in. Sizes. Spuds shall be either flanged or tapped, as called for. Flanges may be either of the round or oval type. If of the round type, they shall conform to the American standard of Jan. 1, 1914. If of the oval type, the drilling shall be on the horizontal axis, and in accordance with the American standard bolt circle. If the spuds are to be tapped they shall be tapped for $1\frac{1}{2}$ and 2 in. respectively, with female thread of standard pipe size, and so tapped that Briggs standard pipe thread plug gages may be screwed in by hand up to the notch on the plug.

Couplings shall be made of bronze composition. Nuts shall be tapped 2 and $2\frac{1}{2}$ in. respectively, straight thread, standard pipe size and so tapped that Briggs standard pipe thread plug gages may be backed into the nuts by hand, i. e., the size of the thread in the nut is the maximum size of the Briggs plug, but no larger. Tailpieces shall be threaded $1\frac{1}{2}$ and 2 in. respectively, male thread, standard pipe size, and so threaded that Briggs standard pipe thread ring gages may be screwed on by hand flush with the face of the gage. 2 by $1\frac{1}{2}$-in. and $2\frac{1}{2}$ by 2-in. standard pipe size malleable iron bushings are to be furnished with $1\frac{1}{2}$-in. and 2-in. couplings respectively. Care shall be taken to see that nuts as above described can be screwed on to the bushings by hand and that the face of the bushings will be sufficiently true and square to provide a proper packing surface.

Over-all lengths of tailpieces shall be:

Size.	Length.
$1\frac{1}{2}$ in.	$2\frac{7}{8}$ in.
2 in.	3 in.

Connections for 3, 4, 6, 8, 10 and 12-in. Sizes. Spuds shall be flanged, faced and drilled. If called for, either companion flanges or bell and spigot connections shall be furnished. Companion flanges shall be of cast iron, faced, drilled and tapped. All flange dimensions, drilling and tapping shall conform to American standard of Jan. 1, 1914. Bell and spigot connections shall be made of cast iron and shall conform to the cast-iron water pipe specifications, class "B," adopted May 12, 1908, by the American Water Works Association as far as these specifications will apply thereto. For the 3-in. size dimensions shall be as follows:

(Letters refer to sketch in Table No. 1 of the A. W. W. A. pipe specifications.)

Actual outside diameter	3.96 in.
Diameter of socket	4.76 in.
Depth of socket	3.50 in.
A	1.25 in.
B	1.30 in.
C	.65 in.

The length of the bell connections from the face of the flange to the seat of the bell shall be 6 in. for all sizes. The length of the spigot connections from the face of the flange to the end of the spigot shall be 18 in. for all sizes.

Seal Wire Holes. All meters shall have register box screws, and one or more bolts of each cover or cap giving access to the working parts of the meter, drilled for seal wire holes. Meters having the by-pass unit in a separate housing shall have the by-pass coupling or connections drilled for seal wire holes. All seal wire holes shall not be less than $^3/_{32}$ in. in diameter.

Measuring Chambers and Cages. The measuring chambers and cages for all meters shall be made of bronze composition, and shall be self-contained and easily detached from their main body casings.

Measuring Pistons. The measuring pistons or discs of the displacement type meters shall be made of vulcanized rubber and shall be fitted accurately but freely in their chambers. Vulcanized rubber disc pistons shall have a metal reinforcement or a thrust roller.

Measuring Wheels. The measuring wheels of the current type meters shall be made of vulcanized rubber and shall be fitted accurately, but freely, in their chambers. The measuring wheel shall

be mounted or shall rotate on phosphor bronze or other suitable metal spindle, and shall be supported by jewel, ball, or other suitable bearings. Measuring wheels mounted on spindles shall revolve in hard-rubber bushed bearings. The measuring wheel, together with its spindle, shall be as nearly as possible of the same specific gravity as water.

Intermediate Gear Trains. The intermediate gear trains shall be of such construction as to be easily removed and shall be made throughout of non-ferrous material. Gear spindles may run in bearings bushed with hard rubber, provided the bushings are so constructed that they cannot drop out.

Strainers. All meters shall be provided with strainers made of or coated with non-ferrous materials. The strainers shall have an effective straining area at least double that of the inlet and shall be accessible for cleaning.

Controlling Valves. The controlling valve mechanism shall be made of bronze composition with phosphor bronze spindles, or of other suitable non-ferrous material. The valve shall cut off all flow through it when the main-line meter is not in operation and shall not bind or stick in service.

Registration. The registration on the meter dials shall indicate the quantity recorded to be not less than 97 per cent. nor more than 103 per cent. of the water actually passed through the meter while it is being tested at rates of flow within the limits specified under "Normal Test Flow Limits," except in the registration of flows within the "change over" from by-pass meter to main-line meter. The registration at these rates of flow shall not be less than 85 per cent. The difference in the rate of flow at the beginning and at the end of the "change over" shall not exceed the figures given in the following table:

Size, Inches.	Gallons per Minute.
1½	20
2	32
3	63
4	100
6	200
8	320
10	460
12	620

The beginning of the " change over " is when the accuracy of registration falls below 97 per cent. due to the automatic valve mechanism, and the end of the " change over " is when the accuracy of registration again reaches 97 per cent.

There shall not be less than 90 per cent. of the actual flow recorded when a test is made at the rate of flow set forth under " minimum test flow."

Size Main Meter, Inches.	Normal Test Flow Limits. (Gal. per Min.)	Minimum Test Flow. (Gal. per Min.)
1½	2 to 100	½
2	2 to 160	½
3	4 to 315	1
4	6 to 500	1½
6	10 to 1 000	3
8	16 to 1 600	4
10	32 to 2 300	8
12	32 to 3 100	14

Capacity. New meters shall show a loss of head not exceeding 25 lb. per sq. in., when the rate of flow is that given in the following table:

Size, Inches.	Gallons per Minute.
1½	100
2	160
3	315
4	500
6	1 000
8	1 600
10	2 300
12	3 100

Pressure Test. Compound meters shall be guaranteed to operate under a working pressure of 150 lb. per sq. in. without leakage or damage to any part.

Workmanship and Material. Compound meters shall be guaranteed against defects in materials and workmanship for a period of one year from date of shipment. Parts to replace those in which a defect may develop within such period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Rejected Meters. The manufacturer shall at his own expense replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

Fire Service Type.

Definition. Meters for fire service are defined as those meters which consist of the combination of a main-line meter of the proportional type for measuring large flows, and a small by-pass meter of the displacement type for measuring small flows, together with an automatic valve mechanism for diverting the small flows through the by-pass meter; the combination affording a clear passage through the meter when the main-line valve is raised from its seat.

Cases. All outer cases shall be made either of bronze composition or of cast iron protected by a non-corrosive treatment. All meters shall have cast on them in raised characters the size and the model, and the direction of the flow through the meter shall be properly indicated. Meters composed of a combination of independent units in separate housings shall have this information cast on each unit. Meters shall be designed for easy removal of all interior parts without disturbing the connectons to the pipe line.

External Bolts. All external bolts shall be made of bronze, or of galvanized iron or steel. Nuts shall be designed for easy removal after having been long in service.

Registers. Registers may be either "round" or "straight" reading, indicating in cubic feet or gallons.

All parts of the registers shall be made of non-ferrous material. The maximum indication of the initial dial and the minimum capacity of the register, when indicating cubic feet, shall be as follows:

Size, Inches.	Maximum Indication of Initial Dial. Cubic Feet.	Minimum Capacity of Register. Cubic Feet.
	Main-Line Meters.	
3	10	10 000 000
4	100	10 000 000
6	100	100 000 000
8	1 000	100 000 000
10	1 000	100 000 000
12	1 000	1 000 000 000
	By-Pass Meters.	
1½	10	1 000 000
2	10	10 000 000
3	10	10 000 000
4	100	100 000 000
6	100	100 000 000

All dials, including the initial dial, shall be sub-divided into ten equal parts. All hands or pointers shall taper to a sharp point. They shall be accurately set and securely held in place.

Register Boxes. Register boxes and lids shall be made of bronze composition or same material as top case, with the name of the manufacturer cast on the lid in raised letters. The same serial number shall be plainly stamped on the lid of both the by-pass and main-line meters. If required, the serial number shall also be stamped on the cases. The lid shall be recessed and shall lap over the box. The glass shall be inserted from the inside and securely held in place without the use of putty or pins. All register compartments shall be provided with a water-escape hole $\frac{1}{8}$ in. in diameter, so placed that the change gear or registering mechanism cannot be tampered with.

Connections. Spuds shall be flanged, faced and drilled. If called for, either companion flanges or bell and spigot connections shall be furnished. Companion flanges shall be of cast iron, faced, drilled and tapped. All flange dimensions, drilling and tapping shall conform to American Standard of Jan. 1, 1914. Bell and spigot connections shall be made of cast iron and shall conform to the cast-iron water pipe specifications, class " B," adopted May 12, 1908, by the American Water Works Association, as far as these specifications will apply thereto. For the 3-in. size dimensions shall be as follows:

(Letters refer to sketch in Table No. 1 of the A. W. W. A. pipe specifications.)

Actual outside diameter	3.96 in.
Diameter of socket	4.76 in.
Depth of socket	3.50 in.
A	1.25 in.
B	1.30 in.
C	.65 in.

The length of the bell connection from the face of the flange to the seat of the bell shall be 6 in. for all sizes. The length of the spigot connections from the face of the flange to the end of the spigot shall be 18 in. for all sizes.

Seal Wire Holes. All meters shall have register box screws, and one or more bolts of each cover or cap giving access to the working parts of the meter, drilled for seal wire holes. Meters having the by-pass unit in a separate housing shall have the by-pass coupling

or connections drilled for seal wire holes. All seal wire holes shall not be less than $^3/_{32}$ in. in diameter.

Measuring Chambers and Cages. The measuring chambers and cages for all meters shall be made of bronze composition, and shall be self-contained and easily detached from their main body casings.

Measuring Pistons. The measuring pistons or discs of the displacement type meters shall be made of vulcanized rubber and shall be fitted accurately but freely in their chambers. Vulcanized rubber disc pistons shall have a metal reinforcement or a thrust roller.

Measuring Wheels. The measuring wheels of the current type meters shall be made of vulcanized rubber and shall be fitted accurately, but freely, in their chambers. The measuring wheel shall be mounted or shall rotate on phosphor bronze or other suitable metal spindle, and shall be supported by jewel, ball, or other suitable bearings. Measuring wheels mounted on spindles shall revolve in hard-rubber bushed bearings. The measuring wheel, together with its spindle, shall be as nearly as possible of the same specific gravity as water.

Intermediate Gear Trains. The intermediate gear trains shall be of such construction as to be easily removed and shall be made throughout of non-ferrous material. Gear spindles may run in bearings bushed with hard rubber, provided the bushings are so constructed that they cannot drop out.

Main Line Controlling Valves. The controlling valve shall be either of the atmospheric or mechanical type, in which the initial resistance to opening practically disappears after opening. The atmospheric valve shall open under a difference in pressure, between the inlet and outlet sides of the meter, not exceeding 6 per cent. of the available pressure. The mechanical valve shall open under a difference in pressure not exceeding 4 lb. to the sq. in.

The controlling valve mechanism shall be made of bronze composition with phosphor bronze spindles or of other suitable non-ferrous materials. The valve shall cut off all flow through it when the main-line meter is not in operation. It shall effectively prevent backflow and shall not bind or stick in service.

By-Pass Check Valve. All meters shall be provided with check valves on the by-passes. The check valve mechanism shall be made of bronze composition or of other suitable non-ferrous material. They shall effectively prevent backflow and shall not bind or stick in service.

Registration. Registration on the meter dials shall indicate the quantity recorded to be not less than 97 per cent. nor more than 103 per cent. of the water actually passed through the meter while it is being tested at rates of flow within the limits specified under "Normal Test Flow Limits," except in the registration of flows within the "change over" from by-pass meter to the main-line meter. The registration at these rates of flow shall not be less than 85 per cent. The difference in the rate of flow at the beginning and at the end of the "change over" shall not exceed the figures given in the following table:

Sizes, Inches.	Gallons per Minute.
3	63
4	100
6	200
8	320
10	460
12	620

The beginning of the "change over" is when the accuracy of registration falls below 97 per cent., due to the automatic valve mechanism, and the end of the "change over" is when the accuracy of registration again reaches 97 per cent.

There shall be not less than 90 per cent. of the actual flow recorded when a test is made at the rate of flow set forth under "minimum test flow."

Size, Inches.	Normal Test Flow Limits. (Gal. per Min.)	Minimum Test Flow. (Gal. per Min.)
3	8 to 400	2
4	8 to 700	2
6	16 to 1 600	4
8	28 to 2 800	7
10	48 to 4 375	12
12	48 to 6 400	12

Capacity. New meters shall show a loss of head not exceeding 4 lb. per sq. in., when the rate of flow is that given in the following table:

Size, Inches.	Gallons per Minute.
3	400
4	700
6	1 600
8	2 800
10	4 375
12	6 400

Pressure Test. Fire service meters shall be guaranteed to operate under a working pressure of 150 lb. per sq. in. without leakage or damage to any part.

Workmanship and Material. Fire service meters shall be guaranteed against defects in materials and workmanship for a period of one year from date of shipment. Parts to replace those in which a defect may develop within such period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Rejected Meters. The manufacturer shall at his own expense replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

HERBERT M. TUCKER.

HERBERT MARION TUCKER was born at Northfield, Vt., in 1867, and died at Lebanon, N. H., May 23, 1922, the adopted son of Mr. and Mrs. Franklin Tucker, of Northfield, who later removed to Lebanon.

His education was that received in the public schools of Lebanon. When a young man he went to Montana, where he had five years of ranch life, ever a most appealing thing to him. He then lived a few years in Providence, R. I., as a telephone linesman, subsequently returning to Lebanon as an employee of the Lebanon Electric Light Company. All the way, from the bottom to the top, did he find himself promoted by his company, until he became general manager. Some seven years before his death his company merged with the Grafton County Light and Power Company, of which he very soon became general manager.

He served Lebanon for several years as one of its fire-wards, a portion of the time being the chief of the fire department.

He also served the town one session as a member of the legislature of the state.

He leaves a widow and a daughter.

He was a member of the Masonic and Odd Fellows organizations.

In his work he was a discreet enthusiast. Seemingly nothing ever tired him. He was almost a model manager, both from the standpoint of his employers and the general public. The people whom he served had faith in him. This confidence was never violated. He did not know how to be mean or to be little. But he did know how to be honest, fair, trustworthy. That was the life he lived. He became the very soul of his corporation, a splendid factor in the life of his community, and when he died all deeply mourned. Surely there can be no higher eulogy than this.

PERCY R. SANDERS,
Committee.

WILLIAM HENRY PITMAN.

Born, January 11, 1851. Died, May 9, 1923.

WILLIAM HENRY PITMAN was born in Fall River, Massachusetts, January 11, 1851. When a youth his family moved to New Bedford, where he attended the public schools, graduating from the High School in 1867. He came from a family which has been prominent in New England since 1663. Mr. Pitman never married.

In 1870 he became a clerk in the New Bedford Institution for Savings, where he advanced in positions of trust for nineteen years. In 1889 he was elected Treasurer of the New Bedford Five Cents Savings Bank, which position he held until January, 1923, when he resigned on account of ill health. Following his resignation, he was elected assistant to the President of the bank, holding that position at the time of his death. He was accepted as an authority in Savings Bank finance through more than half a century.

He held many positions of responsibility in New Bedford, including three years in the City Council, nineteen years on the School Board, and six years as a Commissioner of Sinking Funds.

He was a member of the New Bedford Water Board from 1906 until his death.

He has been a member of this Association since March 11, 1908.

As a private citizen and public official, he always stood out as an example of faithful and conscientious performance of duty and will be greatly missed by a large circle of friends and relatives.

For the Committee,

FREDERICK H. TABER,
S. H. TAYLOR.

PROCEEDINGS.

February Meeting.

Boston City Club,
Tuesday, February 13, 1923.

The President, Mr. Percy R. Sanders, presided.

The Secretary reported that the following had been elected members of the Association by the Executive Committee at their forenoon meeting: George G. Weeks, Trustee, Kennebec Water District, Fairfield, Me.; Charles E. Kendall, Retired Water Commission, Winchester, Mass.; Dexter P. Cooper, Hydraulic and Sanitary Engineer, Buffalo, N. Y.; Harry N. Lendall, Associate Professor of Civil Engineering, New Brunswick, N. J.; Horace J. Cook, engaged in water-works construction and operation, Auburn, Me.; Daniel M. Sullivan, Engineer of High Pressure Fire Service, Water Division, Boston. — 6.

Report of Committee on Laws relating to Financing Water Works.

PRESENTED BY CHARLES W. SHERMAN.

To the New England Water Works Association: The Committee on Massachusetts Laws relating to Financing Municipal Water Works submits the following report of progress:

Bill Introduced in Legislature. The January meeting of the Association authorized the Committee to introduce a bill on behalf of the Association looking towards the accomplishment of such portions of its program as the Committee thought practicable. After careful consideration the Committee decided to introduce a bill which would amend the general laws, *first*, by striking out the clause containing the 5-year limit on bonds for water-works extensions and *second*, by providing for a 30-year borrowing period for practically all major items of enlargement or improvement of water-works systems; — leaving for the future the other matters in which it is believed changes in legislation or new laws are desirable. The bill introduced, which is numbered as *House Bill No. 661* and has been referred to the Committee on Municipal Finance,* is as follows:

> Section 1. Section eight of chapter 44 of the Revised Laws, as amended by section eleven, chapter four hundred and eighty-six of the acts of nineteen hundred and twenty-one, is hereby further amended by striking out the whole of said clause (4) and inserting in place thereof the following: —

* The members of this committee are as follows:
Senators: John Halliwell, New Bedford; Alvan E. Bliss, Malden; George D. Chamberlain, Springfield; Edward J. Cox, Boston.
Representatives: George J. Bates, Salem; George H. Newhall, Lynn; Ernest A. Larocque, Fall River; Andrew P. Doyle, New Bedford; James M. Hunnewell, Boston; Albert A. Sutherland, Boston; Elmer E. Dawson, Winthrop; John E. Beck, Chelsea; Michael E. Jordan, Lawrence; Charles H. Slowey, Lowell; Valmore P. Tetreault, Southbridge.

(4) For the extension of water mains or replacing inadequate mains by pipes of larger size; for constructing, extending, enlarging or replacing pumping stations, pumping equipment, filtration plants or equipment; for the construction or enlargement of reservoirs, or standpipes; for the construction of wells, collecting galleries, intakes, conduits and aqueducts; and for the purchase and installation of water meters; thirty years.

Section 2. This act shall take effect upon its passage.

The Committee has just announced the date of hearing on this bill, February 21. It is obviously desirable that as many as possible of the Massachusetts members of the Association and other persons interested in the passage of this legislation should attend the hearing and should request their senators and representatives to record themselves in favor of the bill, and later, should the bill be recommended by the Committee, urge its passage by the legislature.

Other Legislation Pending. Although foreign to the scope of this Committee's work, there are other items of legislation pending in the general court, which it may not be out of place to call to the attention of the Association. Among these are the following:

House Bill 352 "to provide access for the public to great ponds." This bill is before the Committee on Harbors and Public Lands and date for hearing is February 16. The dangers of making access to great ponds used for water supply any easier than at present are, of course, obvious.

As an instance of the dangers of such access, it may be noted that *House Bill 652*, to authorize the inhabitants of Marlboro to fish in Sudbury Reservoir, was before the Committee on Metropolitan Affairs which reported adversely. Upon the vote being taken in the House there was a margin of but two votes (102 to 100) in sustaining the Committee. Obviously, therefore, the dangers of legislation permitting fishing in our water-supply reservoirs are still such as to give serious concern to those charged with the protection of the supplies.

House Bill 644 "prohibiting the shutting off of water by cities and towns" is before the Committee on Legal Affairs and date for hearing is also February 21. This bill would prohibit the shutting off of water for non-payment of water rates, but as an alternative would make water rates a lien upon the real estate. While the latter provision is desirable, it should not be attained at the expense of the right to shut off water.

House Bills 20 and 181, which are before the Joint Committee on the Judiciary and upon which hearings were held on January 31, would make water rates a lien upon the property. The former applies to the city of Boston only, and the latter to the State as a whole.

House Bills 776 and 777, which are before the Committee on Public Safety and upon which hearings are announced for February 15, provide for inspection of all reservoir and mill dams within the state.

Respectfully submitted,

BERTRAM BREWER
LEONARD METCALF
A. R. HATHAWAY
CHARLES W. SHERMAN
Committee.

FEBRUARY 13, 1923.

THE PRESIDENT. This, as I understand it, is simply a report of progress.

I was interested in looking at *House Bills 20* and *181*. What you do in Massachusetts of course has no bearing on New Hampshire, but I see that the city of Boston is trying to get a bill through making water rates a lien on the property. I was somewhat surprised in looking through the laws of New Hampshire recently to see that the city of Portsmouth has done just that same thing. We tried to get a bill through the Legislature making it state wide, but it seems they got busy and had a bill passed through simply for the city of Portsmouth.

The subject of a satisfactory return for water sold to takers owning more than one house upon a lot or parcel, and who are supplied with water taken through a single meter located on the property, was discussed by Messrs. A. A. Dickerman, H. J. Goodale, Reeves J. Newsom, Henry V. Macksey, George W. Batchelder, Stephen H. Taylor, William F. Sullivan and Henry T. Gidley.

Mr. Philip W. Ayers, Forester of the Society for the Protection of New Hampshire Forests, gave a talk illustrated with the stereopticon, on "Reforestation of Water-sheds."

Messrs. Alexander Orr and Richard A. Hale made some remarks on this subject. On motion of Mr. Samuel E. Killam, Mr. Ayers was given a rising vote of thanks.

A paper on "The Application of a Booster Pump to a Gravity System of Water Supply," was read by George F. Merrill, Superintendent Water Works, Greenfield, Mass. Mr. Merrill also showed some stereopticon views.

President Sanders and Mr. John L. Howard took part in the discussion.

(*Adjourned.*)

MARCH MEETING.

CITY CLUB, BOSTON,
Tuesday, March 13, 1923.

Vice President George A. Carpenter in the chair.

The Secretary announced that the Executive Committee had elected to membership Harry E. Holmes, Resident Engineer, State Department of Public Health, Malden, Mass.

On motion of Mr. Frank A. Marston, it was voted to authorize the President to appoint a Nominating Committee to nominate officers for the annual meeting.

The Association voted unanimously to approve the actions of the Executive Committee in discharging the following committees:

Committee on Standards of Purity for Water.

Committee to Consider and Collect Data on Assessments of Cost of Main Pipe Extensions and the Relation of New Street Layouts or Connections therewith.

Committee on Methods of Extending the Influence of the Association.

Committee on Statistics of Water Purification Plants.

Committee on Activities and Program of the Association.

Committee on Leakage of Pipe Joints.

Committee on Proposed Standard Schedule for Grading Cities and Towns of the United States with Reference to Fire Defense and Physical Condition.

Committee on Uniform Accounting.

Mr. Charles W. Sherman submitted the final report of the Joint Committee of the American and New England Water Works Associations on Standard Specifications for Water Meters.

It was voted that the report be accepted, that the Standard Specifications be adopted "when and if approved and adopted by the American Association" and that the committee be discharged.

On motion of Mr. Caleb M. Saville a rising vote of thanks was given Mr. William W. Brush and Mr. Edward Neubling for their work on the Standard Specifications for Water Meters.

Dr. Charles E. Lucke of Columbia University, gave a talk on The Diesel Oil Engine. Dr. Lucke's remarks were supplemented as to special features by Rodney D. Hall of the Worthington Pump Machinery Corporation, by Mr. H. M. Chase and by Mr. M. Spillman. Messrs. Vernon F. West, Frank A. Marston, Samuel A. Agnew, A. O. Doane and Frank A. Barbour took part in the discussion.

MR. FRANK A. BARBOUR. Mr. Chairman, I am sure we all feel that we have had a wonderfully profitable afternoon. I came to this meeting looking forward to hearing Dr. Lucke speak, having heard him speak before, but he has gone beyond my anticipations. I think this afternoon has proof of the value of having the representatives of commercial organizations speak to an Association such as this. The engineers who are right in their subjects know far more than any of the consultants can possibly know.

I rise to move a vote of thanks to the speakers of the afternoon.

(The motion was duly seconded and unanimously carried.)

(*Adjourned.*)

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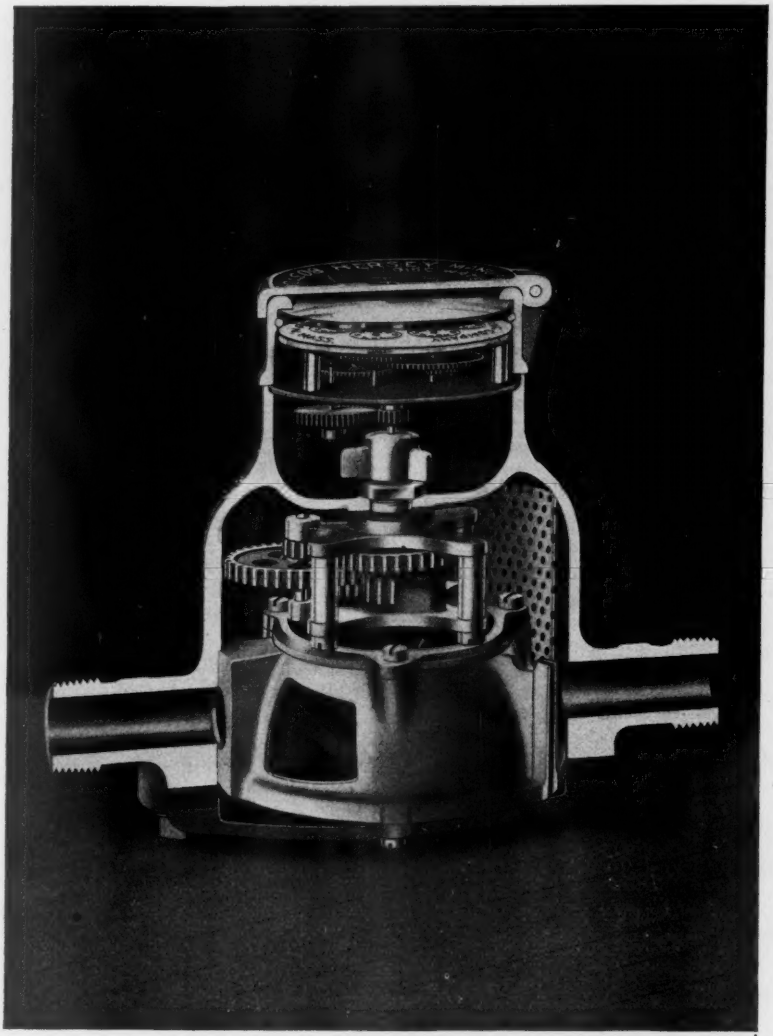

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CHICAGO, ILL. . . . . 10 So. La Salle Street
ATLANTA, GA. . . 610 C. & S. Bank Building
LOS ANGELES, CALIF., 218 E. Third Street.

FROZEN!—but not damaged

Here is an actual photograph of a LAMBERT Frost-proof Meter which has been frozen to an extent that would put the ordinary meter completely out of commission.

This is made possible by a patented, non-corrosive yielding bolt device which allows the upper and lower casing, disc chamber and gear train to part without damaging the meter in any way. Five minutes' labor the only repair cost.

The expense and annoyance from frozen water meters can be eliminated for all time through the installation of the LAMBERT Frost-proof.

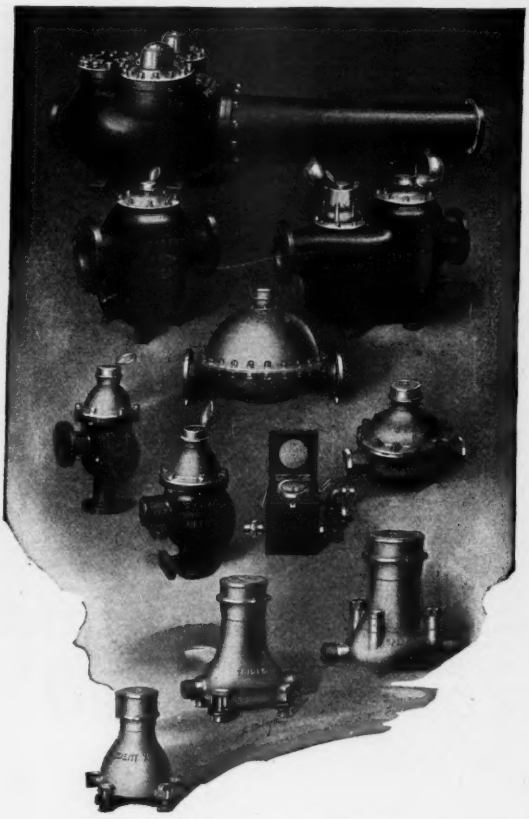
It has been proved that the LAMBERT is the easiest water meter to take apart and put together again as well as the simplest, most reliable and accurate.

If you are interested in other types of meters, we make one for every requirement.

THOMSON METER COMPANY

100-110 BRIDGE STREET BROOKLYN, N. Y.

LAMBERT FROST-PROOF METERS



A Trident for Every Service!

WHY are there more than two million TRIDENTS in service?

There is only one reason,—TRIDENTS are more continuously accurate, more durable, more economically maintained. They are the *best* meters. Don't stint quality — you need the best for *your* services!

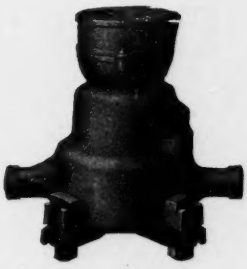
Have you seen our latest development,—the Trident (enclosed) Gear Train?

NEPTUNE METER COMPANY

50 EAST 42d ST., NEW YORK CITY

Atlanta **Boston** **Chicago**
St. Louis **Denver** **Portland**
San Francisco **Los Angeles** **Seattle**

WATER METERS



ARCTIC—*a frost-bottom meter for Domestic Services.*

KEYSTONE—*an all bronze meter for Domestic Services.*

EUREKA—*a current meter for large and rapidly flowing volumes of water.*

KEYSTONE-COMPOUND—*for services requiring accurate measurement of small as well as large volumes of water.*

PITTSBURGH METER COMPANY

East Pittsburgh, Pa.

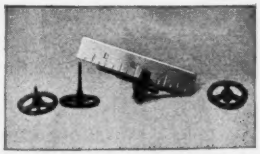
SALES OFFICES:

NEW YORK - - - -	50 Church St.	COLUMBIA, S. C. -	1433 Main St.
CHICAGO - - -	5 S. Wabash Ave.	SEATTLE - - -	4038 Arcade Bldg.
KANSAS CITY - - -	Mutual Bldg.	LOS ANGELES - -	Union Bank Bldg.

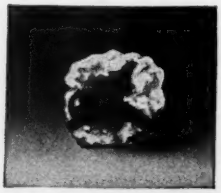
What Freezing Did Not Do

These two pictures show the intermediate gears of a Worthington Model "G" Meter. In one the train is encased in a solid block of ice, just as the parts were taken out of a completely frozen meter. After the ice melted the other photograph was made to show that no damage was done. Gears, train plate and casing, all came through the freezing totally unharmed. The only parts which suffered were four little bronze frost clamps, replaceable for a few cents. This shows some of the things that do *not* and *cannot* happen when a Worthington meter freezes. Those little frost clamps are certainly cheap insurance against the ravages of zero weather.

WORTHINGTON



Showing the gears, pinions and train plate after thawing. Not a single part has been warped or distorted in the least. The straight edge across the face of the train plate shows clearly that the original shape has not changed.

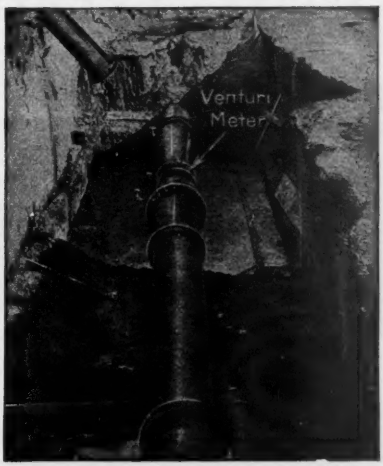


The intermediate train just after it was taken out of a standard Worthington meter. Note how completely the gearing is encased in ice.

WORTHINGTON PUMP AND MACHINERY CORPORATION

Executive Offices: 115 Broadway, New York City

Branch Offices in 24 Large Cities



WHILE THE TRENCH IS OPEN

is the time to install Venturi Meter Tubes in the pipe line, whether it is new construction or repairs and changes to old lines. Much expense and inconvenience is saved by doing the whole job at one time.

VENTURI METERS

Should be placed in every main pipe line of every water works system. Practically all large cities of the United States and Canada have accepted the above statement and adopted it as standard practice for both pumping lines and gravity mains. They realize it is just as important to meter main supply lines as to meter individual services to users. The cost of a Venturi Meter Tube is not greatly in excess of the straight pipe it replaces and the friction loss is negligible. If you contemplate new work or repairs why not put in Venturi Meters now? You will eventually.

Send for Bulletin No. 210

Builders Iron Foundry

PROVIDENCE, R. I.

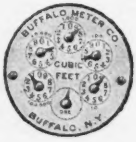
AMERICAN AND NIAGARA WATER METERS

5/8 INCH NEW AMERICAN WATER METER

5/8 INCH NEW NIAGARA WATER METER

Niagara and American Meters are of the disc type. The Niagara Meter has a galvanized cast-iron outside casing; the American Meter has a bronze main casing with either a bronze base or a galvanized cast-iron base. The works in the three different casings are the same and interchangeable. Upon opening the meter at the bolted flange, each intermediate gear may be immediately removed from its bearing, the measuring chamber lifted from its seat, the strainer slipped out, or the register tried by turning the stuffing box gear. All submerged working bearings are protected against sand and sediment. The hard rubber measuring disc is reinforced with a metal plate. Purchaser has option of round reading or straight reading register indicating cubic feet, U. S. gals., imp. gals. or litres.

Round Reading Register



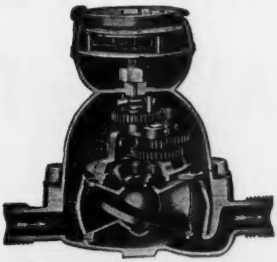
Straight Reading Register

BUFFALO METER CO.

ESTABLISHED 1892

2896 Main Street BUFFALO, N. Y.

UNION WATER METERS



King Model "B" Disc Meter

WATER METERS

cannot be any better than their gear trains, and the life of the gear train is determined by its ability to withstand corrosive conditions.

Hard rubber bushed spindles, intermediate spur gears of hard rubber and phosphor bronze have been a feature of Union Water Meters for forty years. In recent years this has been further perfected by the adoption of Monel Metal for spindles and screws.

The buoyancy of rubber spur gears renders the meter more sensitive and minimizes wear.

Makers of Approved Water Works Specialties since 1868

Union Water Meter Co.

WORCESTER, MASS.

WATER WASTE SURVEY
PAYS for ITSELF

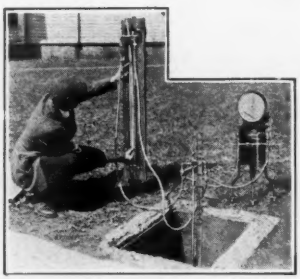
Every water waste survey thus far made by the Simplex Valve & Meter Company has revealed a waste of water, the cost of delivering which for one year has far exceeded the total charge for making the survey.

Simplex water waste surveys check up the performance of your pumps, the registration of your meters and through subdividing the distribution system into districts, locate leaks in mains or house services, broken mains, blown joints and other losses.

The organization of the Simplex Valve & Meter Company includes a corps of engineers thoroughly experienced in this work and their services as well as the use of the Simplex water waste instruments are at all times available for the use of water departments and water corporations.

SIMPLEX VALVE & METER CO.

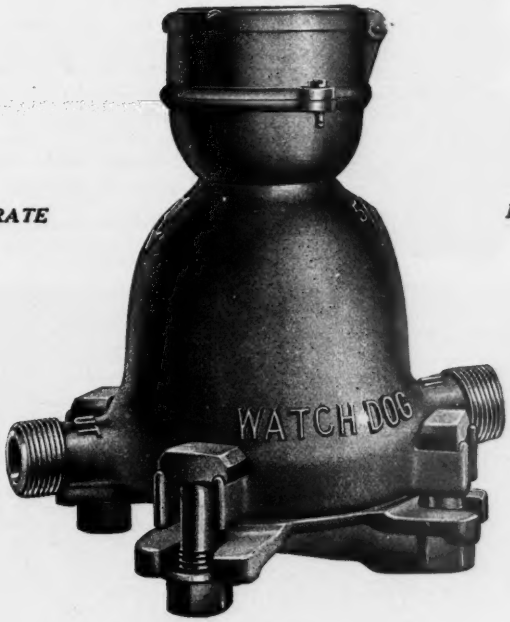
5729 RACE STREET, PHILADELPHIA, PA.



A Simplex Pitot tube recorder set up over a water main for testing flow during water waste survey.

"WATCH DOG" WATER METERS

ACCURATE *DURABLE*



DISC, CURRENT AND COMPOUND TYPES

Inquiries Solicited

GAMON METER COMPANY

NEWARK **NEW JERSEY**

WATER METERS

NASH
TYPE K
DISC METER

THE nutating disc meter is an old friend of ours. The Nash is the first meter of this type that patent was ever applied for in this country, and has been on the market since 1888. Every new feature that test and experience have shown to be an improvement, we have built into the Nash Type K, which we consider the best disc meter made.

POINTS TO INVESTIGATE

THE Nash Type K is a well designed, substantially built, all bronze meter. It can be furnished in two styles, either with or without frost protection feature. The construction is simple and the meter can easily be taken apart without removal from the service pipe. Nash Type K has a split case, without screws; ready drainage; enclosed intermediate; straight reading register; and large slow-moving disc.

WHEREVER disc meters are specified the Nash Type K will meet every requirement, and give lasting satisfaction.

Send for fully descriptive pamphlet No. 200

NATIONAL METER COMPANY

299 BROADWAY, NEW YORK CITY

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ATTENTION
WATER WORKS
OF NEW ENGLAND

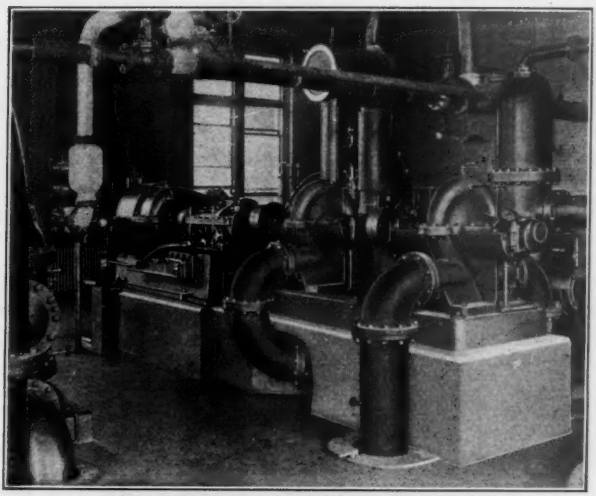
A few reasons why we solicit your inquiries on Water-Works Pumping Equipment:

First. — We make a specialty of furnishing Complete Water-Works Pumping Units of all types.

Second. — Total responsibility of installation is assumed by us.

Third. — We relieve the purchaser of every detail and turn the complete unit over to him under actual operation and with guarantee.

Fourth. — Every unit installed to date has exceeded its guarantee and has been completely accepted.



Turbine-driven Pump at the Arlington Station of the Metropolitan Water Works, Boston, Mass.

F. A. Mazzur & Co.

141 MILK STREET, BOSTON

Test of Centrifugal Pumping Set

at City of Woburn Water Works

CONTRACT CONDITIONS AND GUARANTEE

PLANT — Morris Machine Works Single Stage Centrifugal Pump Direct Connected Through Reduction Gear to a Multistage Condensing Kerr Steam Turbine.

CAPACITY — 5,000,000 gallons per 24 hours.

HEAD — 239 feet dynamic.

DUTY — 94,000,000 foot pounds per 1,000 pounds of dry steam at 115 pounds gage pressure.

TEST RESULTS

WATER PUMPED — 3,334 gallons per minute.

DYNAMIC PUMPING HEAD — 240 feet, including 18 foot suction lift.

STEAM USED — 4,040 pounds per hour.

PRESSURE AND QUALITY — 111.5 pounds gage, moisture 1.4 per cent.

BACK PRESSURE — 1 inch Hg. Absolute.

DEVELOPED DUTY — 99,078,751 foot pounds per 1,000 pounds of dry saturated steam at 115 pounds pressure supplied at the throttle. Excess duty, over 5 per cent. On this basis — with steam costing 50 cents per 1,000 pounds — the cost of pumping the water is about $10 per million gallons.

The first cost of this turbine driven centrifugal water works pump with surface condenser and steam driven air pump, was approximately one third the cost of a crank and flywheel reciprocating unit, of the same capacity.

Note the low steam pressure and absence of superheat, a condition typical of many existing water works plants. A duty of nearly 100,000,000 foot pounds is regularly obtained.

Equipment installed according to plans and specifications of

H. M. HAVEN & W. W. CROSBY, INC., Engineers
40 COURT STREET BOSTON, MASS.

CONTRACTORS

STARKWEATHER & BROADHURST, Inc.

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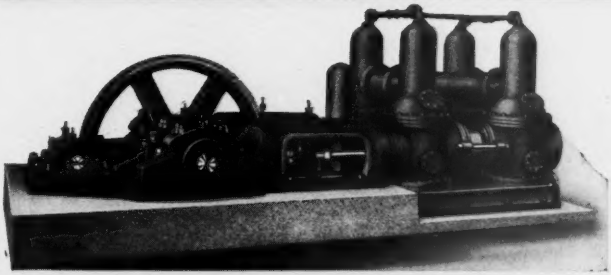

PLANT EFFICIENCY—77% ON 1-YEAR RUN
WIRE TO WATER

HAYES PUMP AND MACHINERY CO.

94 PEARL ST., BOSTON, MASS.

Pumping Plant Contractors

CENTRIFUGAL, POWER, STEAM PUMPS

STEAM TURBINES
WATER WHEELS

ELECTRIC MOTORS
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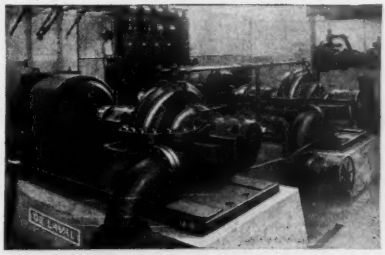

Typical Small Electrically Operated Centrifugal
Municipal Water Works Installation.

POWER EQUIPMENT COMPANY
BOSTON

There was not a single death from Typhoid Fever in Providence in 1923

The Providence Journal
THURSDAY, JANUARY 4, 1923

PROVIDENCE HAS NO TYPHOID FEVER DEATH DURING 1922

A remarkable freedom from typhoid fever deaths, which Superintendent of Health Chapin says has never been equaled by any city the size of Providence in the country up to 1922, was enjoyed by this city during the year just closed. According to statistics compiled by the health department, there was not a single death from typhoid in Providence during the year

In 1919 the city of Spokane, Wash., which then had a population of [illegible] 104,000, went through the

Providence, like 3000 other American Municipalities uses 'W & T' Apparatus to Sterilize EVERY DROP of its Water Supply with Liquid Chlorine.

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COMPANY INCORPORATED
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Health and Protection First

Water delivered through dirty pipes
may be a MENACE.

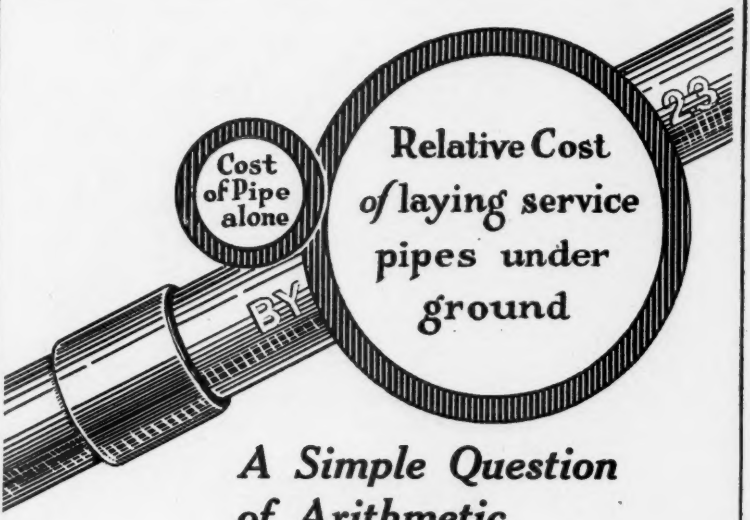
Incrusted water pipes mean inefficiency
and loss of Fire Protection.

We Guarantee the Results of Our
Method of Cleaning.

WRITE US.

National Water Main Cleaning Co.

50 Church Street New York City



A Simple Question of Arithmetic

The cost of a length of service pipe is trifling compared with the cost of laying it. In case of failure of the pipe, the loss of water, labor of digging up and renewing a pipe, still further multiplies the installation cost.

The lasting quality of the pipe, depending on its rust-resistance, is therefore the first thing to be considered by the majority of experienced water works engineers and superintendents. Hence the extensive use of Byers pipe for underground water service.

The chemical and physical properties of genuine wrought-iron and their bearing on the question of rust-resistance, are interestingly dealt with in Byers Bulletin No. 6-A. Write to A. M. Byers Company, Pittsburgh, Pa., for a free copy.

BYERS PIPE

GENUINE WROUGHT IRON

Look for the Name and Year rolled in every length

H. W. CLARK CO.
1740 Broadway Mattoon, Ill., U.S.A.
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Manufacturers of the well-known CLARK METER BOX, maintaining uniformity for both large and small meters. Standardization in meter installations saves you money. Everything for the Water Works.

Write for new catalogue No. 20.

GEO. E. GILCHRIST CO.
Manufacturers and Jobbers of
Steam, Gas and Plumbing Materials
WROUGHT IRON PIPE
Railway, Water Works and Sanitary Supplies
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CAST IRON BELL AND SPIGOT WATER PIPE AND FITTINGS
FLANGED PIPE in full and short lengths
WROUGHT PIPE
FRED A. HOUDLETTE & SON
(Incorporated)
93 Broad Street, Boston, Mass.
Quotations furnished promptly for shipment from Foundry

BRAMAN, DOW & CO.

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READING IRON PIPE
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HIGH GRADE BRASS FITTINGS
VALVES AND COCKS
SERVICE AND VALVE BOXES
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239-245 CAUSEWAY ST., BOSTON, MASS.

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"CALDWELL" WATER WORKS BRASS GOODS AND CURB BOXES
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REDUCING, REGULATING & RELIEF VALVES
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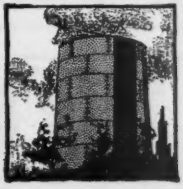

Standpipes
Water Tanks
Gas Holders
and all other metal surfaces need the protection of
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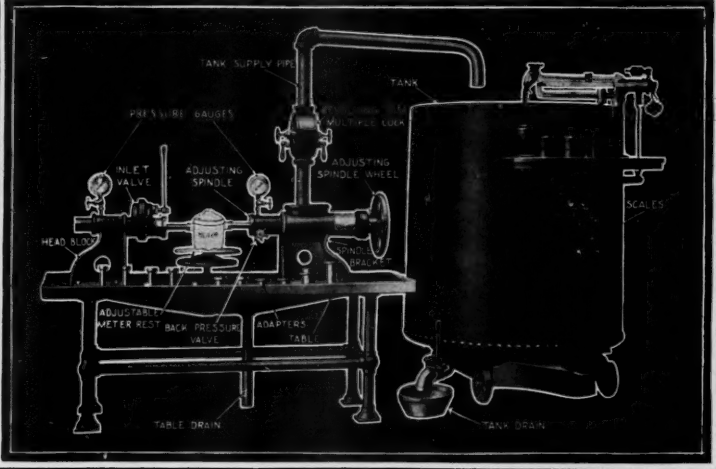
JOSEPH DIXON CRUCIBLE CO. Jersey City, N. J.



The People Demand Increased Efficiency

You can make sure your Department gets full revenue for every gallon of water used—by seeing that all meters are regularly tested for accuracy—with the

Mueller Water Meter Tester

The Mueller will prove exactly what each meter does—will enable you to adjust each meter to absolute accuracy—will save more than its cost year after year. Used and endorsed by leading municipalities. The name Mueller guarantees both Quality and Service.

Detailed description and prices on request.

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400 CHESTNUT STREET, PHILADELPHIA, PA.

Engineers, Iron Founders and Machinists

CENTRIFUGAL PUMPS
PUMPING ENGINES

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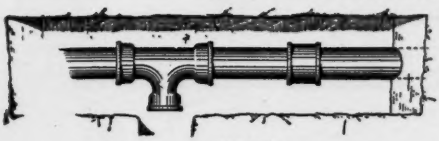
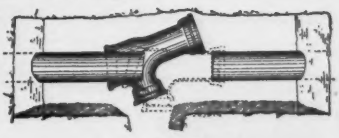
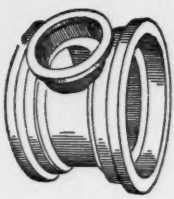


Old Way



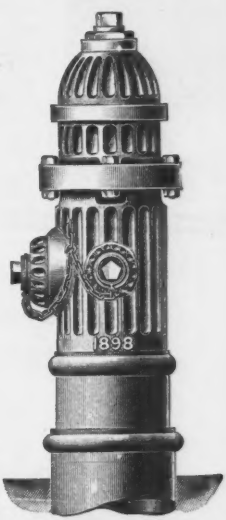
Our Way



Connections economically and easily made with one fitting. Saves sleeve, cuts, lead and unnecessary work and material.

"Reduced Specials"

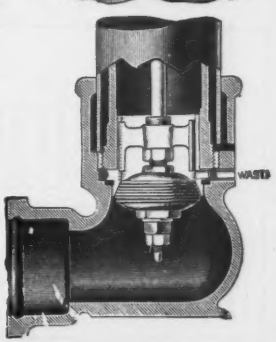
Cost of fittings reduced from 25% to 50%. Full strength. Deep bells. Convenient to handle. Sold by the piece.



Mathews Fire Hydrants

A half century of use has established their reputation as being the most economical, durable and simple hydrant.

Number in use exceeds total of all other makes combined.



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R. D. WOOD & CO. STANDARD
DOUBLE DISK
ANTI-FRICTION
EXTRA WEIGHT, FINISH
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Ware Coupling & Nipple Co.

WARE, MASS.

Grip Pipe Fittings and Brass Nipples

WATER
FILTERS
REGULATORS
& ENGINES

We make **Pressure Regulating Valves** for all purposes, steam or water.

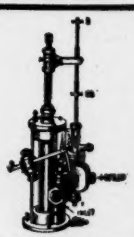
Our **Feed-Water Filter** will keep oil out of your boiler.

We can interest you if you use a condenser.

Water Engines for Pumping Organs

THE ROSS VALVE MFG. CO.

TROY, N. Y.

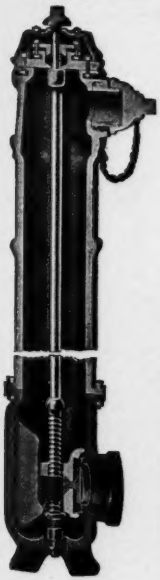


Standard for pumping church or parlor organs. Ask your organ builder for it or write us.

Coffin Valve Co.

NEPONSET, MASS.

Sluice Gates, Gate Valves and Fire Hydrants



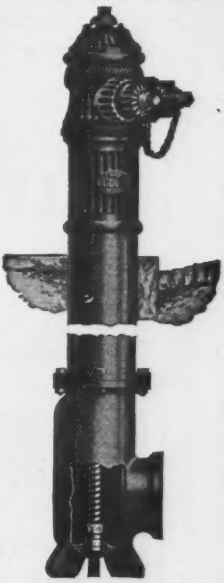
LUDLOW VALVE MFG. CO.

MANUFACTURERS OF

VALVES and FIRE HYDRANTS

This hydrant is anti-freezing, because when the drainage is good no water is left in it to freeze.

The drip is directly in the bottom of the hydrant and drains perfectly. It is protected by its valve, which never leaves its socket and cannot be clogged.



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ALSO CHECK **VALVES,**
FOOT **VALVES.**

FIRE HYDRANTS.

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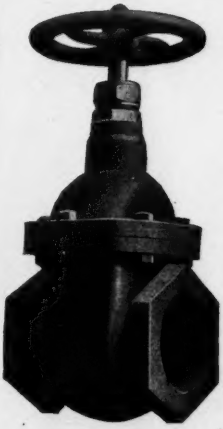

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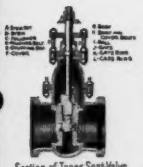
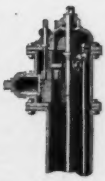
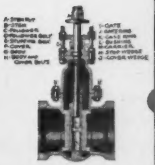


Section of Taper Seat Valve.



Hydrant with Independent Nozzle Cut-off.



Section of Parallel Seat Valve.

Section of Vertical Check Valve.

Section of Vertical Foot Valve.

Horizontal Check Valve.

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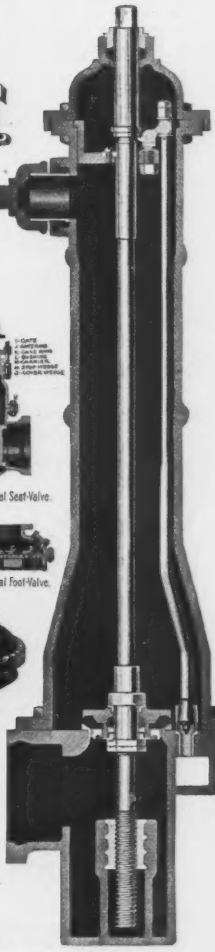
Indicator Post.

Water Crane with Automatic Drip Valve.



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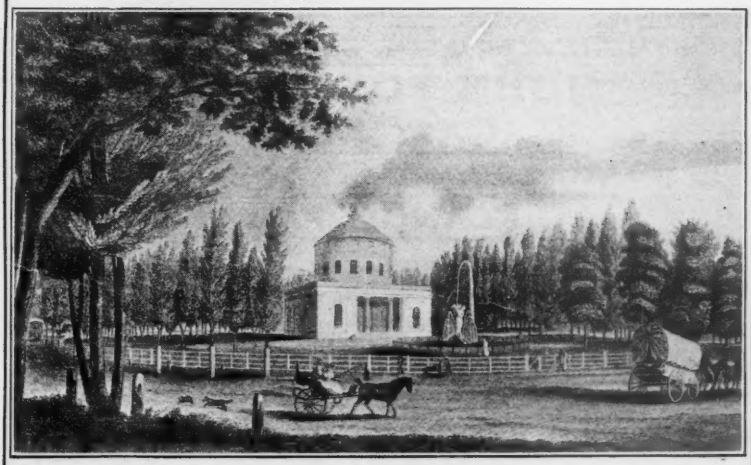

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In 1842 Charles Dickens wrote the above description of the Philadelphia Water Works. At that time cast iron pipe, in Philadelphia, had been delivering water faithfully for 25 years. Nor was its usefulness nearly over. In 1915 the pipe illustrated was removed, though still in good condition after almost a century of service, to make way for a line of larger capacity.

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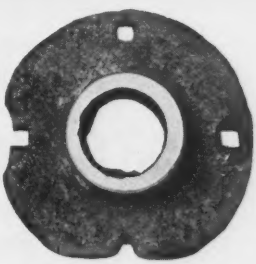

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ST. LOUIS EXPOSITION, 1904

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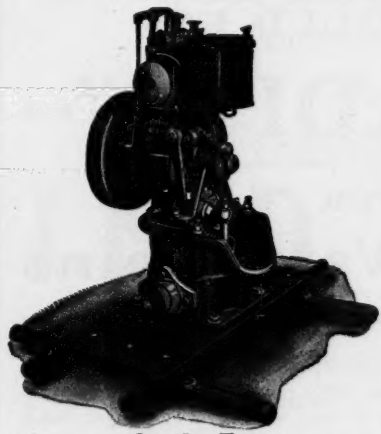

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50% SMALLER BELL HOLES

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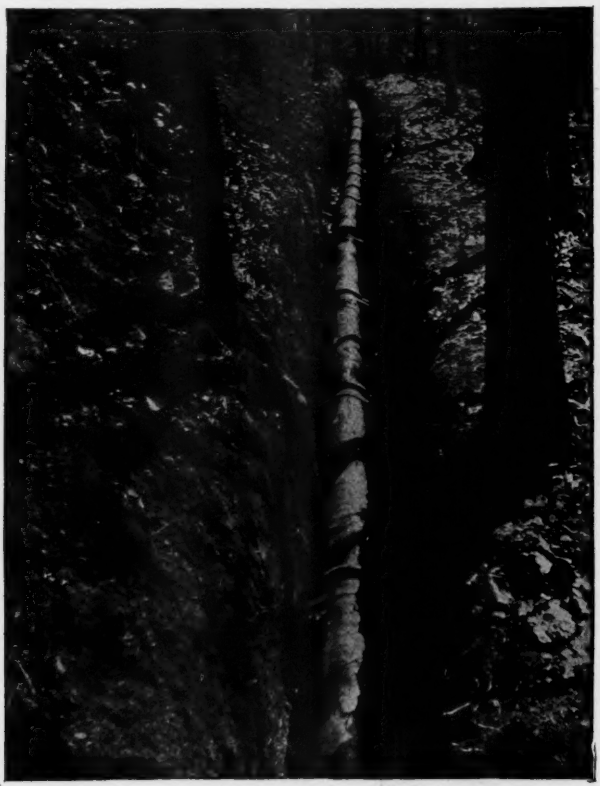

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ORGANIZED JUNE 12, 1882.

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(*resident, non-resident or associate*)

.....*membership.*

I am.....*years of age, and I have been engaged in the following named work:*

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I will conform to the requirements of membership if elected.

Signed,.....

Address,.....

Dated,.....*19*

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